POWER PLANT ENGINEERING

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Meeting Increased Demands

PUMPING STATION AT TOLEDO, OHIO, REBUILT WITHOUT INTERRUPTING SERVICE; ENGINEERING WORK CARRIED ON UNDER ADVERSE CONDITIONS

NOT UNTIL 1873 was the pumping and distribution of water a function of the municipality of Toledo, Ohio. During the first year of the life of this system but 12 services, fed by 8.49 mi. of piping, were in use and although no record of the total amount of water handled during this period is available, statistics indicate that during 1876, 4 yr. thereafter, the average daily pumpage was 2,176,266 gal. or a total of approximately 796,513,356 gal. Forty-six and one-half miles of piping and 1213 services were then in use.

Gradually as the population of the city increased the demand for water for domestic, industrial and fire protection purposes became greater and greater until during the last year, that is, 1920, the average daily pumpage was 25,208,705 gal. which was served through 428.52 mi. of pipe line and 50,779 service outlets.

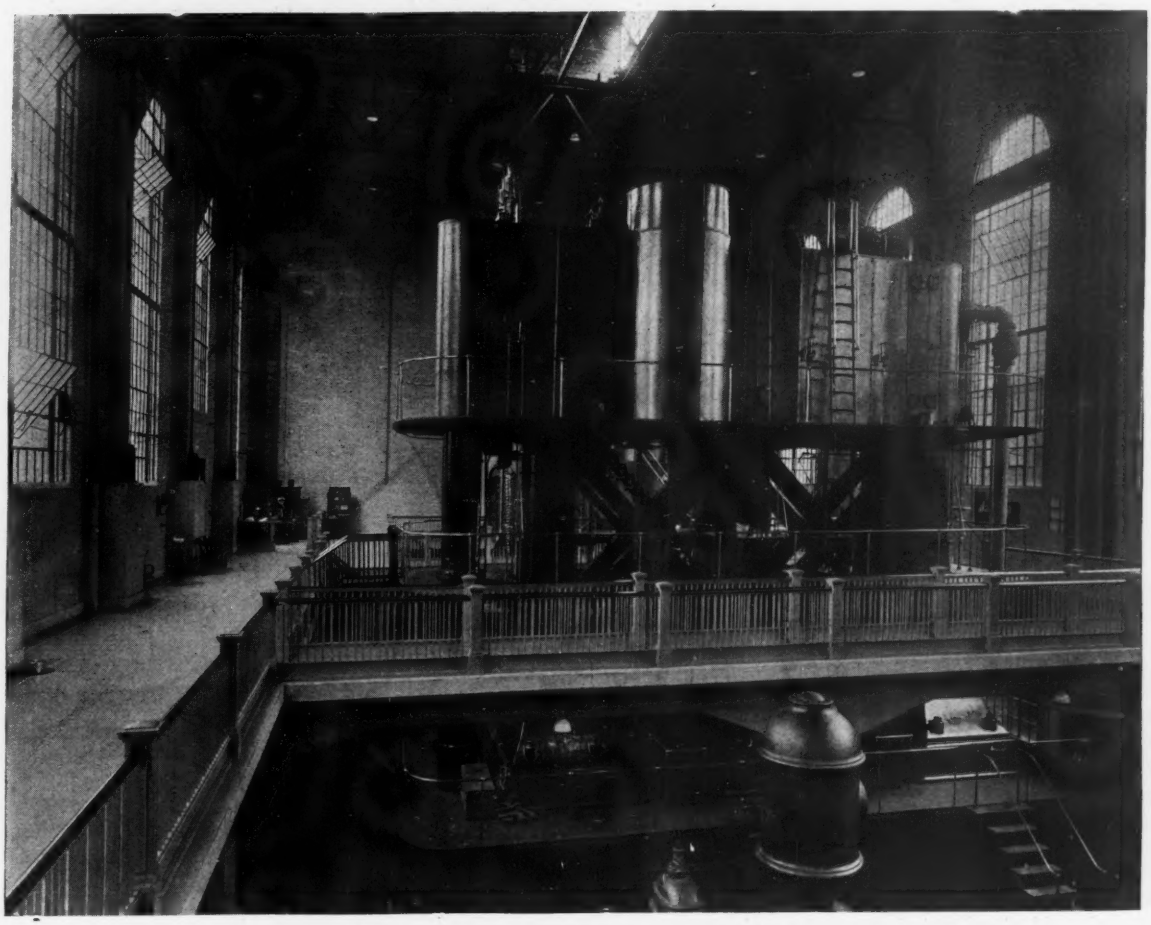

FIG. 1. INTERIOR VIEW OF ENGINE ROOM SHOWING 30,000,000-GAL. PUMPING UNIT

Since the inception of the system and up to the present date but a single central high-pressure pumping plant has been employed and while many changes in and additions to the plant have been made from time to time according to the requirements of the service, all of the water supplied has been through the pumps of the Broadway station. This, as shown in Fig. 6, is located on a triangular plot of ground along the banks of the Maumee River and bounded by Broadway, Stebbins St. and Water Works Drive. Formerly water was taken directly from the river and pumped either directly into the mains or as requirements demanded into a 228-ft. 60-in. steel standpipe enclosed in a masonry structure. In 1910, however, a filtration and purification plant was placed in operation at Nelson Ave. and River Road about 2½ mi. southwest of the Broadway station and since then all of the water supplied has been taken through intakes connecting with this installation. After treatment, the water flows by gravity through a 72-in. conduit laid along Broadway and terminating in a well adjacent to the high-pressure plant, this well connecting as indicated in Fig. 7 with a 15,000,000-gal. clear-water basin and the pump intakes through 60-in. conduits. With the employment of this arrangement, independent operation of the purification and high-pressure plants is possible; surplus delivery from the former is cared for by the clear-water basis while, if due to necessity or otherwise, the purification plant may be shut down for any but an extended length of time, no service interruptions will result.

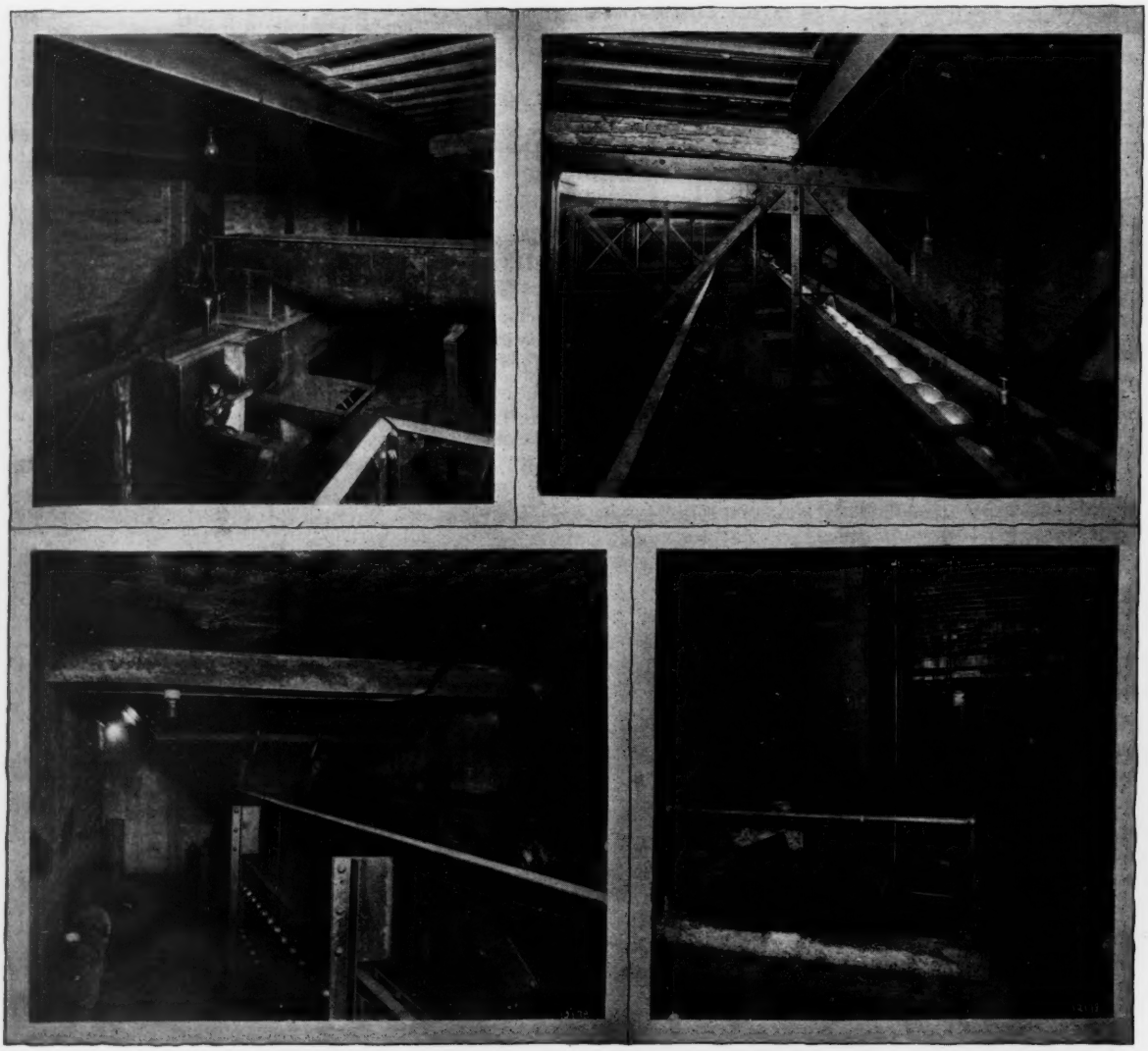

FIG. 2. DETAILS OF COAL-HANDLING EQUIPMENT

Immediately upon completion and the placing in operation of the filtration and purification plant in 1910, the load upon the system became so great as to necessitate the taking of steps to increase the capacity of the pumping station. Appropriations for this work, first, because of political influence and, second, on account of conditions arising out of the World War, were not forthcoming as rapidly and as continually as may have been desired, with the consequence that the rehabilitation was of necessity a piece-meal process extending over a period

of 10 yr. Among the first steps taken, however, was the installation of a 30,000,000-gal. triple-expansion crank-and-flywheel pumping engine in the central section of

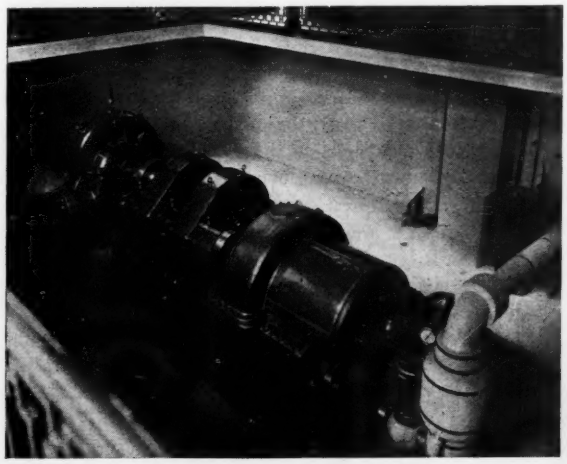

FIG. 3. RECENTLY INSTALLED 30,000,000-GAL. TURBINE-DRIVEN CENTRIFUGAL PUMP

the pump room, enlarged to accommodate it. Following this was the erection of the new building—see Fig.

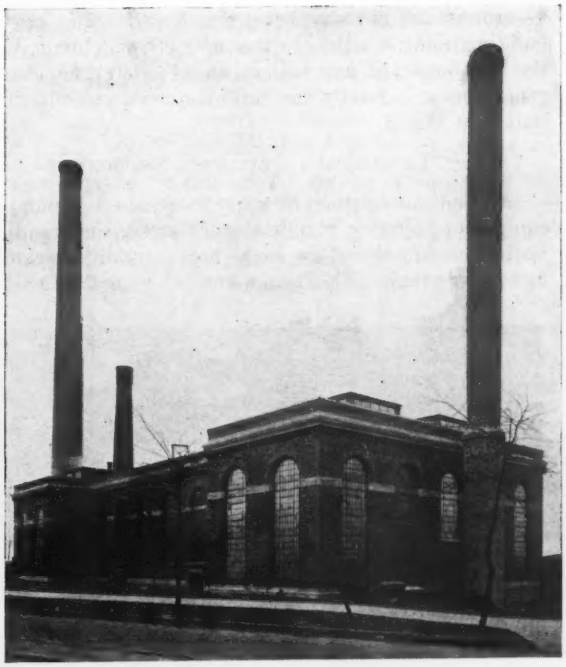

FIG. 4. EXTERIOR OF BROADWAY PUMPING STATION

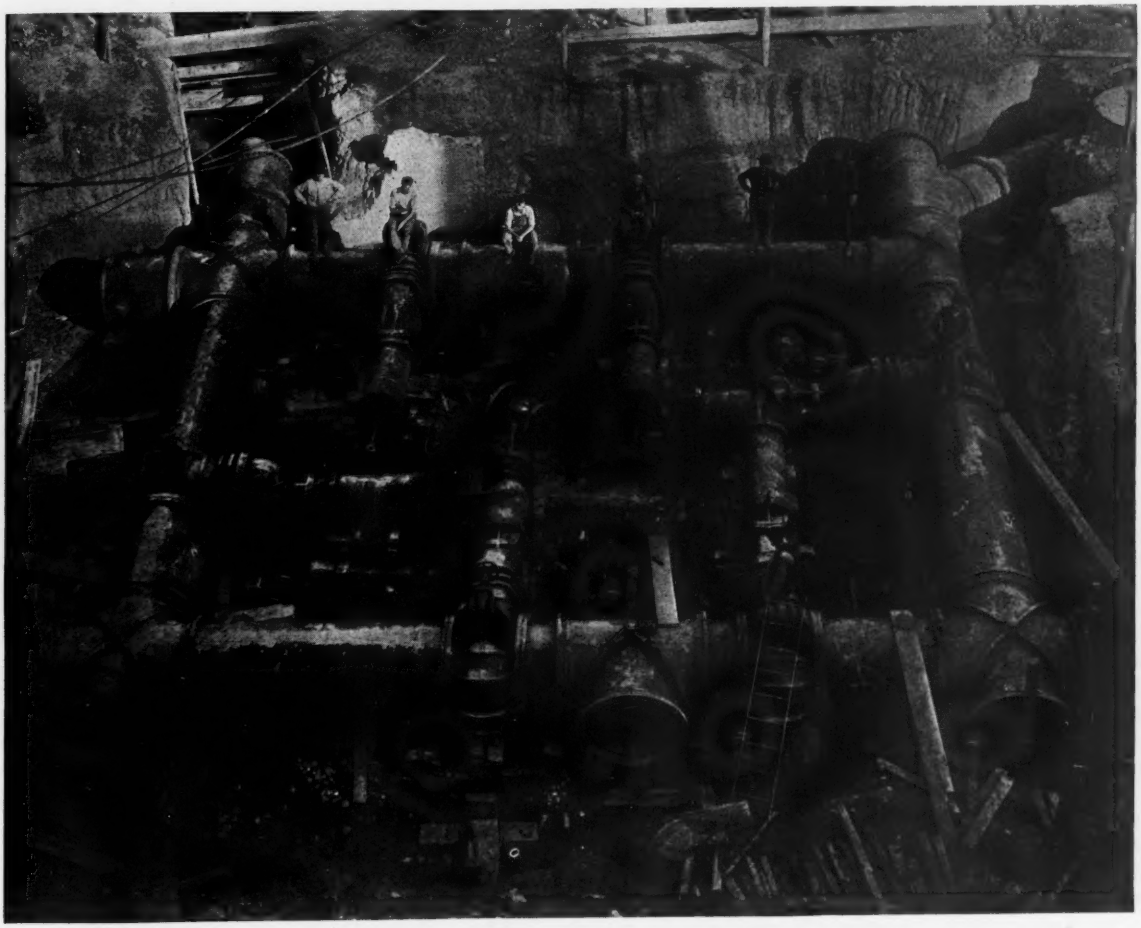

FIG. 5. FORTY-EIGHT-INCH HEADER SYSTEM—BROADWAY STATION

4—around the old structure, the demolition of the old building, and then the erection of a 225-ft. chimney and the installation of new boilers, an electric crane, electric generators and finally the turbine-driven pumping unit shown in Fig. 3.

Eliminating Standpipe Service

As the consumption of water increased and pumping equipment capacity remained unchanged, the standpipe no longer functioned as such, but in reality became a mere surge tank. This being coupled with the fact that fact which remained undiscovered by anybody for a period of more than 2 yr. Thus convinced, all concerned agreed to the futility of further retaining this fixture and accordingly in 1916 it was razed.

The Present Pump House

Except for some few minor finishing touches, the new Broadway pumping station of the City of Toledo is now a reality. Truly it may be said that all that remains of the old plant is the site. The building which is of steel, concrete and brick construction throughout

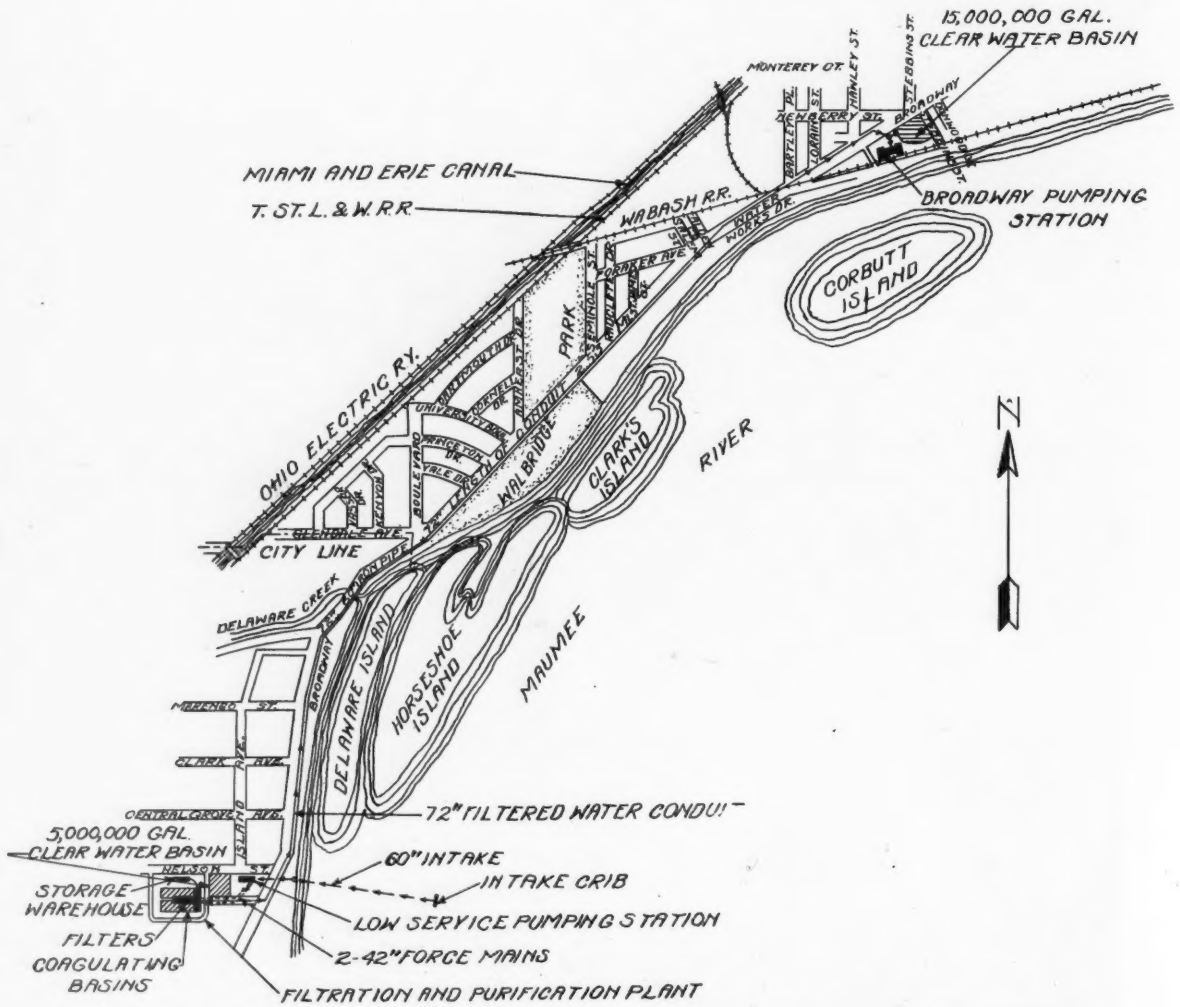

FIG. 6. MAP SHOWING LOCATION OF FILTER PLANT, LOW-SERVICE PUMPING STATION, 72-IN. CONDUIT AND BROADWAY PUMPING STATION

the structure was rapidly deteriorating and because of its close proximity to the plant, the existence of the standpipe became a source of possible danger and accordingly its removal was suggested. Opposition was, however, at once raised against this procedure both from many citizens and operatives at the plant who felt that with the standpipe gone shutting down of the pumps would result in a complete tie-up of the system. While such an occurrence was possible, it was, however, improbable and in order to substantiate their claims that a standpipe was unnecessary the engineers advocating its abolition secretly disconnected it from the system, a

consists, as shown in Figs. 4 and 7, of a central section housing the main pumping equipment and two end wings; the one to the south being the boiler room proper, while the other is a combination boiler and turbine room and machine shop. The steam-generating units installed in the south wing are reserve boilers and are retained in use for emergency only. Each of these is of the water-tube type, has a capacity rating of 400 hp. and when used is hand fired.

In the main boiler room are now installed four 500-hp. water-tube boilers equipped with underfeed stokers which are fed by means of a 1600-lb. traveling

weigh larry installed for that purpose. The coal is delivered to the plant in cars placed on a siding of the Wabash Railroad, the tracks of which as shown in Fig. 7 skirt the property on the south. It may be carried directly to the boiler-room bunkers or placed in a 1500-ton submerged storage bin as operating conditions may require.

The boiler-room bunkers have a capacity of 575,000 lb. (surcharged, 700,000 lb.).

The coal-handling equipment installed is most complete in every particular. That delivered directly to the station is dumped into a tank hopper and from there carried by means of an apron conveyor made up of 126-c malleable roller chain with double beaded flights 30 in. long to a 24 by 24-in. crusher of the single roll type. After being reduced to the required size the coal is then taken up by the 7 by 14-in. buckets of an elevator traveling at a speed of 200 ft. per minute and rated at 30 tons per hour, which discharge it into a 12-in. spiral conveyor, 44 ft. in length, and which in turn feeds it to a second spiral conveyor of like diameter but 79 ft. long for final distribution to the bunkers.

Pumping Equipment

This consists essentially of six units, five of which are of the reciprocating type while the other, the most

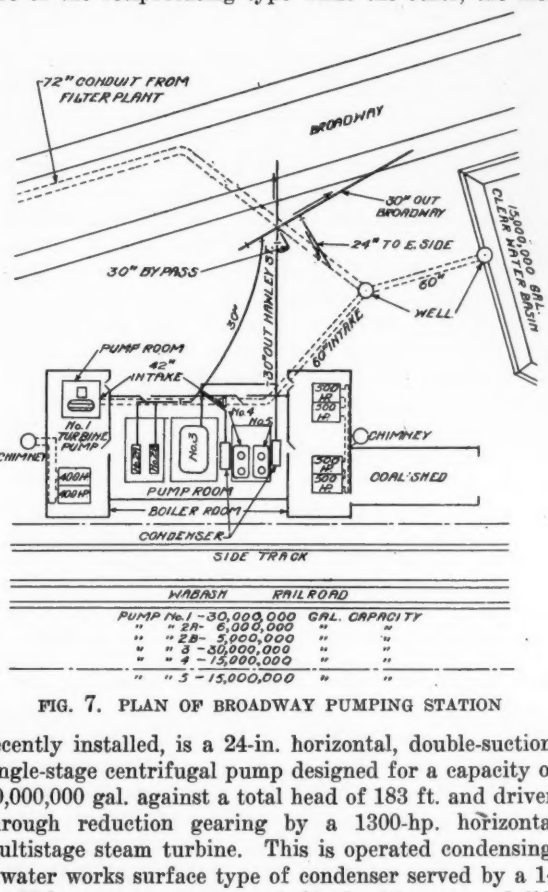

FIG. 7. PLAN OF BROADWAY PUMPING STATION

recently installed, is a 24-in. horizontal, double-suction, single-stage centrifugal pump designed for a capacity of 30,000,000 gal. against a total head of 183 ft. and driven through reduction gearing by a 1300-hp. horizontal multistage steam turbine. This is operated condensing, a water works surface type of condenser served by a 14 by 28-in. vacuum pump and fitted with a geared lift pump to elevate the condensate above a desired head having been installed for the purpose. Both vacuum and lift pump are driven by a 6 by 6-in. vertical self-oiling engine.

The other pumping units installed have rated capacities of 5,000,000, 6,000,000, 15,000,000, 15,000,000 and 30,000,000 gal. respectively and are all operated condensing.

The New Header System

In referring to this header system in his article entitled "Revamping Toledo Pumping Station Under Service," appearing in the June 17, 1920, issue of the Engineering News-Record, George N. Schoonmaker, water commissioner of Toledo, writes as follows:

FIG. 8. INTERIOR OF BOILER ROOM AT BROADWAY PLANT

"The header system is in a concrete underground structure covered with a concrete slab roof. It is built up of 48-in. cast-iron pipe, special castings and six 48-in. hydraulically operated gate valves which are so placed that by shutting off two valves any line leading from the header to the city or from the station to the header can be closed off without interrupting the flow of water from or to the header through the other lines. The valve control is manipulated from a special operating table of the type ordinarily used in filter plants. This table, which is located in the main pumping station building, is fitted with three-way cocks and is provided with an indicating dial attached to each 48-in. valve. Water pressure for operating the valves is obtained both from the force mains and from an auxiliary connection to the boiler feed-pump system in the station.

"The piping and valves are placed upon the lower courses of masonry formerly supporting the standpipe and are blocked up on concrete piers so that all parts are accessible. The ball and spigot joints are poured full depth with lead and calked inside and out. The six valves have flanged connections to the pipe system.

After the header system had been tested to 150 lb. per sq. in., the joints recalked where necessary and the header retested, a concrete floor was poured and the walls and roof constructed.

"The entire work of installing and constructing the header system was done by the employes of the water department using a 40-ton stiff leg derrick with an 80-ft. boom. In order to aline the header connections with the pump discharge of the force mains leading to the city, it was necessary to tilt the whole system of piping; the discharge side taking an angle from the horizontal and the entrance side taking an angle directly opposite. With castings of the size used this work was difficult but was accomplished with precision and all discharge and entrance connections were made to meet the exact elevations of the old piping.

"The header system has been designed to care for a total of 120,000,000 gal. of water per day, the present momentary peak demand is 52,000,000 gal. and the average daily consumption 24,000,000 gal."

Safety Features of Steam Boiler Accessories*

Discussing the Safety Features of a Number of Devices Used in Connection with Modern Boiler Room Practice. By Warren Hilleary

BEING WITHOUT knowledge of the difference between accessories, apparatus, appliances and fittings, as applied to steam boilers, I have selected a few of those devices which I consider accessories, and have treated each in the order of their seeming importance:

Safety Valves

There should be at least two safety valves on every steam boiler for the reason that if only one valve is provided it may fail. It is evident that if there are two or more safety valves there will be less likelihood of excess pressure being raised on the boiler than if only one is used. We are assuming that the combined capacity of the valves is proper and in accordance with modern standards.

The question of mounting the valves on a "Y" or other base, the single outlet of which connects with the boiler, has been frequently debated upon, and apparently there is no objection to the "Y" base.

It is difficult to mention safety features of the valve itself which have not already been taken care of by manufacturers of approved valves. When the valves are constructed of approved materials, equipped with the correct spring for the pressure to be carried, and have the desired angle of disc and seat, there is little further to be said, except that there must be an easily accessible means of lifting the disc from the seat for testing purposes, "easily accessible means" to be interpreted as indicating that the attendant must be able to lift the disc from the seat while the boiler is under pressure, without danger of burns on hot parts, without having to grope about for a cord or lever, without climbing a ladder, and, preferably, from a point when the pressure gage and the water gage glass can be viewed while the disc is being held off its seat. In operating practice, it too frequently occurs that the boilers are being worked beyond normal rated capacity, and if the water chances to be quite high in the boiler, the lifting of the disc when the gage pressure is up to within a pound or two of the blowing point, may cause water to be carried into the steam line. If both the pressure gage and the water gage glass are visible from the point where the disc may be raised, the action of the water in the glass will very often indicate to the attendant whether the disc should be instantly dropped or whether it is safe to hold it open for a few seconds. Theoretically, the lifting of the disc under any conditions will not cause water to be carried into the steam line, but, in practice this frequently occurs. Where the boiler load is intermittent, which is also a frequent occurrence, it is often necessary to carry the water very high in the boiler during periods of the lesser steam demands, in order that when greater steam demands are suddenly made, it will not be necessary to pump feed water rapidly into the vessel, thus making it more difficult to maintain the necessary steam pressure.

The discharge outlets of the safety valves should, of course, be so arranged that there will be no likelihood of any person being scalded, nor having dust blown into his face and eyes when the safety valves open, but it is not desirable that the outlet should be piped farther than absolutely necessary. The piping should be as straight as possible and with no more than one bend or elbow in the line. The bend or elbow should be provided with at least a 1-in. free drain at the lowest point, except that if the discharge outlet is less than 1 in., then the drain need not be so large. There are cases on record where persons have been scalded by safety valve discharge and also where severe eye injuries have resulted from dust on the boiler tops being blown into the eyes of attendants. In some plants, a ¾-in. pop valve is installed on each boiler, and set 2 or 3 lb. lighter than the main safety valves. The blowing of this pilot valve, which makes considerable noise, is a warning to the attendants that the main valves are about to blow, and I am not sure that it is not a good idea to place these pilot safety valves on every boiler, for the expense is not considerable and there is, no doubt, an advantage in knowing that the main valves are about to blow.

Water Gage Glass

It is generally conceded that the gage glass should be provided with a guard to prevent flying particles of broken glass from striking the attendants, but it is not easy to obtain guards which will leave a free and unobstructed view of the water level when the water column is located 10 or 15 ft. above the boiler-room floor. This is not an uncommon height on several types of boilers. Gage glass guards of a suitable and efficient nature are limited to a very few, and unless the purchaser chances to select one of these few the result is dissatisfaction and the discarding of the guard. Since the breaking of the gage glass is a common, expected and unavoidable occur-

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rence, and since many severe injuries have been received from flying particles of glass, it is evident that operators should make every effort to secure a proper guard and be willing to experiment to some extent in the endeavor to get one which is efficient and at the same time does not obstruct the view of the water level.

The newer forms of connections for the gage glass permit considerable misalinement of the glass and more expansion than the types heretofore used, so that glasses will be breaking less frequently; but no device, other than a guard around the glass itself, may be expected to eliminate the danger incident to a breaking glass. Until very recently the tightening of the gage glass

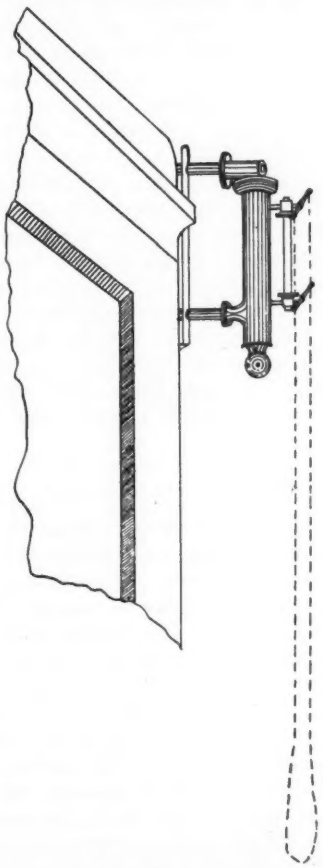


FIG. 1. SAFE TYPE OF GAGE GLASS VALVE AND WELL PROPORTIONED WATER COLUMN

gasket or washer was done by revolving a hexagonal nut. The action of revolving this nut put a considerable twisting strain on the glass. The latest device is in the form of the ordinary packing gland and follower and puts no twisting strain on the glass. In addition to this valuable feature, it permits great misalinement of the glass. The only safe gage glass valve is the quick opening, chain operated type, which permits the operator to stand some distance from the glass and control the line of steam and water to it by merely pulling on one of two chains either to open or close the valves as the case may require. With the screw type of gage glass valve it is necessary for the operator in opening and closing the valves, to expose himself to the danger of a glass breaking, and the exposure is for a considerable length of time since it takes considerable time either to open or close the two valves.

Gage Cocks

THE NON-THREAD weighted, or self-closing gage cocks, have many advantages over the screw type, and can be used to more advantage in a greater number of places than the screw type, the latter being improper for any condition except locomotive work where the vibration and jar is so great that the screw type is better. The only reason that the self-closing type has not met with more favor, is because attendants will not give them the attention to which they are entitled, with the result that they leak. With reasonable care, and it is expected that all mechanical equipment should have this, the self-closing gage cock will outlast any other, is far safer than the screw type and the attendants using them are in no danger of being scalded through causes attributable to the type of valve; whereas, with the screw type, scalding is not uncommon. There are cases where the valve was screwed entirely out, thus allowing a stream of hot water to discharge from the valve opening, with no way to stop it except to relieve the boiler of all pressure.

Water Columns

THE COLUMNS of many of the older installations are frequently of insufficient capacity, and while, theoretically, water seeks its own level, it is a fact that the gage glass frequently shows a false water level where the column capacity is too small, and the installation of a modern type of column and its equipment is a good investment for any boiler user who may at present be using the older types of small columns, scarcely larger in internal diameter than the pipes to which they connect. Obviously, since the purpose of the column is to show a still water level in the boiler, it follows that it should be of sufficient capacity to insure the least possible agitation. The difference of opinion as to whether the column connection should be equipped with stop valves is considerable, but there is scarcely greater excuse for stop valves on the water column connections than there is for stop valves between the safety valve and boiler, and water column stop valves will eventually be closed at a time when they should be open; at least we are led to that conclusion when we remember that it is always the unloaded gun which kills. It is admitted that there are advantages in having stop valves on the water column connections, especially in territories where boiler feed water is quite bad, for water with considerably solid in it causes accumulations of this solid, whatever it may be, in and on the parts of the gage cocks, with the result that they leak more or less. With the stop valves in the water column connections, the column may be shut off and the valves repaired without blowing down the boiler. I think, though, that the disadvantages of having the stop valves outweigh the advantages.

High and Low Water Alarms

THESE ALARMS have their advantages, but they also have their disadvantages. In my opinion they should not be used, for the simple reason that attendants invariably come to rely solely on the automatic action of the alarms, with the result that frequently the water

level runs dangerously low, through failure of the alarm, and it would seem that the attendant should not have duties sufficiently multitudinous to prevent him from properly watching the water level through the gage glass and the testing of the gage cocks.

Pressure Gages

These instruments as a rule do not cause accidents, and yet, if they are not equipped with a siphon in the form of a loop or "U" bend, the tube will shortly harden and cause the gage hand to show improper reading.

Blowoff

A common danger which has, without any good reason, existed for many years, exists in the use of a 2½-in. diameter blowoff pipe on certain types of water-tube boilers. The type referred to has a drum capacity of about 44 cu. ft., and, under average conditions, the drum

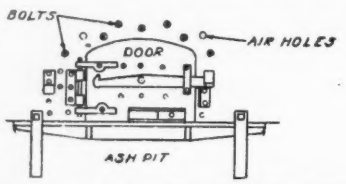


FIG. 2. SIMPLE TYPE OF DOOR LATCH

would be half filled with water during normal operation, that is, there would be, roughly, 20 to 25 cu. ft. of water in the drum. With 160 lb. gage pressure, which is the normal pressure for the type, it is possible to blow all the water out of the drum in between 8 and 10 sec., which means that even with quick opening and closing blowoff valves, the attendant would have great difficulty in properly blowing the boiler down without blowing out so much water as to leave the drum and certain of the tubes empty and exposed to the hot furnace gases. It is strange that the manufacturer, the user, and the multitude of inspectors do not realize this danger and reduce the diameter of the blowoff pipe to 1½ in., which would be ample for the particular type referred to. A boiler with less than 75 cu. ft. of water between the point registered by the center of the gage glass and the highest point of contact with the furnace gases, and carrying a pressure of 160 lb., should have a blowoff pipe no greater than 2 in. in diameter. With any larger diameter the proper blowing down of the boiler will lower the water level to below the highest point of the gases and thus create a dangerous condition. Our boiler codes give us the minimum and maximum diameter of the blowoff pipe, without taking into account the cubical capacity of the boiler. The size of the blowoff equipment on fire-tube boilers is seldom found to be too great for the water capacity of the boiler, but on water-tube boilers it is frequently found to be too great. Attendants soon learn that they cannot, with safety, open the blowoff valve wide when blowing down, so they adopt the practice of opening it only part way, the result being that proper blowing down is not accomplished, and sediment lodges in the valve, causing various inconveniences, expensive repairs, and danger.

It seems desirable that the boiler code should take into account the proper area of blowoff pipe with relation to the pressure carried, and the cubical contents of the boiler between normal water level and the lowest safe water level.

Non-Return Valves

Among many dangerous practices continually going on, at least two stand out. While they are not related to each other, they seem to exist pretty well together in power station work. The one is the synchronizing of two alternators by guess, that is, by watching the effect of the current alternations on an incandescent lamp. The other is the cutting in of a boiler on a header which is being supplied by other boilers. The guess work on synchronizing not infrequently throws the whole system out of step, and the guessing of the proper time to open the stop valve from boiler to header sometimes results in disastrous explosions. In the first case, a very simple and inexpensive synchronizing indicator is purchasable and absolutely reliable. In the second instance, a much cheaper and simpler device, in the form of a non-return valve, is procurable which will not only prevent the boiler from being cut into the line too soon, but will also protect the entire system in the event of a tube bursting in one boiler. Non-return valves are a necessity, but education of the user into the necessities of having non-return valves is an inordinately slow process. If it is not beyond the jurisdiction of the boiler code to deal with non-return valves, then certainly the code should state that non-return valves should be used on every boiler connecting to a header with one or more other boilers.

Rotary Tube Cleaners

Rotary tube cleaners, motor or turbine driven, are the only mechanical means for cleaning the interiors of tubes of water-tube boilers. With curved tubes, the cleaner, in its efforts to follow a straight line through the curved tube, more or less rapidly wears away the metal of the tube at certain points near the bends, and not infrequently the tubes are so thinned by the cleaner that they burst during operation. There is no object in running the cleaner through the tubes until there is some scale present. The greater the amount of scale the slower the cleaner will travel through the tube, and, since the rotary speed of the cleaner is constant, it follows that if it stands still, or practically still, at any one point in the tube, and its cutting parts continue to revolve, a spot in the tube will be worn by the cutters. The extent of this wearing cannot be determined by any process of inspection; therefore, a danger is present, the character of which makes it highly advisable that the boiler washer be most carefully instructed in the proper use of the cleaner, having the dangers of improper use explained to him, and further advisable that tubes which are apparently still good should be cut out at certain intervals, depending upon the frequency of use of the cleaner, and replaced with new ones; the old one being examined at the curves by sawing through to determine the remaining thickness. Steam turbine cleaners have an added danger of the steam hose bursting, and this hose, in addition to being wire wound, should be discarded and replaced with a new one at least twice each year, regardless of the amount of actual use, for both the rubber and the fabric used in the manufacture

of the hose deteriorate with age, and bursting steam hose has caused a great number of very serious accidents.

Concrete Floors Under Boilers

If concrete floors are not accessories, they nevertheless deserve comment when they form the bottom of the ash pit and combustion chamber of any type of boiler in localities where the atmospheric temperature reaches or falls below the freezing point. A substantial concrete floor laid on clay, or almost any soil other than dry sand, becomes dangerous when heated through to a temperature of more than 212 deg. F., for the moisture which collects under the floor is converted into steam by the heat, and there is probability of the floor being burst with great violence, due to the pressure under it. There are records of accidents resulting from what amounted to an explosion of the floor, caused by steam pressure forming under it, and quite naturally, before a substantial floor can be burst by steam pressure, acting upward under it, the pressure must be quite high; it just as naturally follows that this high pressure, when instantaneously released, must be expected to do considerable damage in the immediate vicinity. The specifying engineer of boiler installations should, therefore, take into account the dangers connected with the use of concrete floors under boilers, when such floors are laid on soil which will not permit any steam formed under the floor, to travel downward, before the pressure generated reaches anything substantially above atmospheric.

Furnace Door Locks

There have been a number of accidents to boiler attendants in the nature of scalds and hot fuel burns, resulting when bursting tubes or flues push open the fire or ash-pit doors and allow steam and live coals to pass into the boiler room, at a point where the attendant may be expected to be stationed. A great many, if not all, of these accidents could have been prevented by the installation of automatic door locks, types of which are now on the market, and which, when the doors are even somewhat carelessly closed by the attendants, still lock, so that no amount of pressure inside the furnace or ash pit will throw the doors open. The objection to installation of the locks is frequently that if the lock is so substantial that it will not break and allow the door to open, then the pressure which would, without the door lock, open the door and be relieved, must then blow out the boiler walls. The proper attitude, however, is to consider that the safety of the attendant is the first consideration; if it is necessary to sacrifice a part of a boiler wall to save the attendant's life, then the wall should be sacrificed. It does not follow, however, that the boiler walls will be blown out by a tube explosion, in the event of the furnace and ash-pit doors being locked, though, admittedly, if a 4-in. tube in a water-tube boiler carrying 160 lb. pressure, burst along 1 or 2 ft. of its length, there will momentarily be a considerable pressure in the fire and gas passages; this pressure may, if the doors are locked, blow down a portion of the boiler walls or lift off the top cover. There are perhaps no more than one or two inexpensive, yet reliable door locks manufactured, and the reluctance of operators to install locks is caused to some extent by the failure of some of the makeshifts which have been installed, but all of those having opportunity to do so should prevail upon operators to install approved furnace and ash-pit door locks.

Steam Flow Meter

This valuable device has not met with the welcome reception to which it is entitled, and there is probably no good reason why every boiler operating in a battery with one or more other boilers should not be equipped with a steam flow meter which will be a positive indication to the fireman that each boiler is, or is not, delivering through its steam line its proper proportion of steam.

In any battery of boilers, even when each boiler has precisely the same theoretical capacity as its fellows, there will be one or more either delivering less steam or more steam than it should deliver, and this inefficient and rather dangerous condition is instantly detected by the reading of the steam flow meter. The increasing or decreasing of the fire intensity can immediately be accomplished to exactly the degree required for the boiler to do its proportion of steaming. Perhaps the safety features of a steam flow meter are greatly outweighed

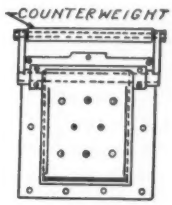


FIG. 3. BALANCED TYPE DOOR. DOOR OPENS INWARD, COUNTERWEIGHT TENDING TO KEEP DOOR CLOSED. INCREASE OF PRESSURE IN FURNACE AUTOMATICALLY CAUSES DOOR TO CLOSE

by their efficiency features. Nevertheless, there is less danger present in the operation of a battery of boilers when each boiler is doing its proper portion of the work than when one or more boilers are doing much more or much less than its share of the work; the danger lying in the probabilities of burning the tubes or sheets of the boilers which are over-fired, and the danger of low water in the same boilers and excess water in the under-fired boilers. These statements do not take into account the ideal condition of boiler operation, which is seldom realized, but instead contemplate average working conditions where some scale is present and where all boilers are fed through a common source.

Oil Burners

All steam or air atomized oil burners either are in themselves dangerous or the equipment necessarily used in connection with them becomes dangerous through their use. Mechanical atomization is reasonably safe; since mechanical atomization is more economical, by a considerable margin, than steam or air atomization, it may be expected that sooner or later all atomization will be done by mechanical process to the complete exclusion of the steam or air process. The most economical steam atomizer oil burner will require from 2 to 4 per cent of

the total steam generated in the boiler for atomization of the fuel oil, whereas mechanical atomizers use none of the power generated by the boiler, exclusively of that required to pump the oil to a given pressure and furnish heat for it, and this power is also required with the steam atomizer. With steam atomization, carbonization takes place at the burner tip, resulting in an unequal spread of the fire, and this, in addition to reducing efficiency, produces a danger, in that it frequently causes the fire to concentrate upon one or more relatively small areas on the tubes or sheets, causing burns and bags.

This condition does not exist with mechanical atomization. The steam or air atomizer will be set to atomize the oil properly at a given boiler pressure which, let us say, is 10 lb. lower than the desired boiler pressure. The attendant regulates the burner to increase the boiler pressure by 10 lb. The multitudinous duties of the average attendant call him to some refractory boiler feed pump, or elsewhere, and while he is busy for 5 min. the steam on the boiler increases the desired 10 lb., with the result that the atomizer valve will pass more steam to the burner than is desirable, and literally blow the fire out. After a few seconds, a quart or more of crude oil has entered the furnace and since there is no flame present, the hot bricks generate explosive gas from the oil. The gas explodes.

Such a condition is altogether unlikely with mechanical atomization. The one possible objection to mechanical atomization is the necessity of bringing the oil to a high temperature before it enters the burner. The temperature is necessary to reduce the oil from a heavy to a light condition, and it seems to be the practice to heat the oil to 250 or 275 deg. F., yet I have learned of no accidents attributable to bringing the oil to a Fahrenheit temperature of 275 deg. Careful damper regulation is paramountly necessary when oil fuel is used. If the attendant is burning coal and forgets to open the damper before firing up after a short or long shut-down, there may not be an explosion of confined coal gas, but with oil fuel it is extremely dangerous to start the fire or admit any oil to the furnace until after the damper may have been opened at least a few seconds, for fuel oil is converted into gas very quickly by relatively low temperatures, and the explosive power of this gas is considerable, so unless the damper is opened wide before oil is admitted to the furnace, an explosion of violence is apt to occur, and not merely blow down a portion of the boiler walls, but injure the attendants.

Explosions of Gases in Fire Boxes

Burns from hot gases passing through the furnace doors into the boiler room are rather too common. These burns are not always caused by explosion of furnace gas, but the person burned and those who may make a perfunctory examination into the case are apt to state that there was an explosion of gas in the furnace.

If a boiler is manually fired and has a thick, long flame, the fire burning with a strong draft, and if, for any reason, the damper is suddenly closed, hot gases and the flames themselves frequently pass through the furnace doors into the fire room, and any person in line with the fire door, and no more than 3 or 4 ft. away from it, is apt to be burned whether he is actually attending to the fire or whether the door was closed.

The sudden closing of the damper is something which does not frequently take place accidentally, although there are one or two types of damper regulators which, under certain conditions of bad repair, permit a rather rapid closing of the damper. None of these regulators, if in good repair, will close the damper rapidly enough to cause flame and hot gases to pass into the boiler room.

Many of the burns from hot gases which pass into the fire room through causes other than the furnace explosions, have been traced to the sudden closing of a manually operated damper, weighted in a manner to hold the damper closed, and it is good practice, therefore, to weight a damper in such manner and so heavily that the damper will open itself. When this is done, danger of the damper accidentally being closed is very slight, and any one of many simple contrivances can be arranged to hold the damper in the closed or any intermediate position against the tendency of the weight to open it.

If a shovelful of very wet coal and as much as a quart of free water is thrown upon a red or black fire, a considerable explosion is apt to result from the water gas, which is instantly formed and ignited, so evidently it is bad practice to stand in front of the furnace door and throw in wet coal and unabsorbed water.

If the damper is partly closed, as is frequently the case in normal operation, to prevent too rapid combustion, any exploding gas in the fire box will be more dangerous to the attendant in front of the fire doors than the same amount of gas would be with the damper wide open.

Where steam blowers are used for forced draft, there is generally considerable piping between the original source of steam and the blower valve. If the blower is not in constant use, condensation takes place in the supply pipe and considerable water accumulates. The opening of the blower valve permits the water in the pipe to be suddenly projected into the ash pit, where the temperature under many normal conditions may be well over 225 or 250 deg. F., and while I am not prepared to say why the explosion should take place in the ash pit, it nevertheless is a fact that this has occurred, burning an attendant severely. Although it may seem that to install a steam trap immediately above the blower valve is an over-precautionary measure, there is at least one case on record which would seem to justify such an installation.

I do not personally know of any instance where the attendant was burned when he opened the furnace door at a time when forced draft was being caused by a steam blower into the ash pit, but I have heard of such cases and believe they occur. The precaution of providing an interlocking device on the furnace door which will shut off the blower before the door can be fully unlatched, and which I understand has been adopted in some of the plants of the DuPont Company, is a valuable one, and its value should undoubtedly be brought to the attention of every user of forced draft, whether the draft is caused by a steam blower or a fan. It is conceivable that the arrangement could be cheaply and satisfactorily installed, and, as long as it was kept in order, would positively prevent the evident danger.

It is thought by some, and I believe not without basis, that the opening of a furnace door, and the resultant admittance of air to the fire box, causes explosion of gases which have accumulated in the space above the fire, even though the damper may be open. It is difficult to see how any considerable quantity of gas would accumulate and remain in the fire box when the damper is open; yet apparently such conditions have existed.

A good many householders who burn coal in some sort of furnace, such as the hot-air type, will have at some time noticed that after filling up the furnace with fresh coal for over-night banking purposes, all flame disappears, and in 5 or 10 min. if the furnace door is opened and a rush of air is caused to enter the furnace door by fanning across the space with a newspaper, or even by blowing into the furnace, there will be a sudden burst of flame up through the coal. While it is not in the nature of an explosion, it is conceivable that if the fire area were large, as it is in the case of steam boilers, and the quantity of coal proportionately large, then the sudden bursting into flame would take the appearance of an explosion.

The only safety measures which suggest themselves to me in connection with prevention of furnace gas explosion, or injuries resulting from unpreventable explosions, are, first, the providing of a proper latch for the furnace door, and, second, the careful education of the firemen in how to perform their duties. It is rather an intangible subject, and one which I find difficulty in discussing, except in the abstract.

Editor's note.—The foregoing paper was prepared by the author in a manner to invite discussion and is presented here for that particular purpose. We shall be pleased to receive for publication the opinions of the readers on any of the subjects discussed.

Methods of Recooling Condensing Water---I*

MODERN THEORY AND PRACTICE OF RECOOLING CONDENSING WATER. BY THE TERRELL CROFT ENGINEERING COMPANY

CONDENSING WATER for steam and ammonia condensers may be used over and over again if some means for recooling it economically is available. Recooling of condensing water may be necessary when, due to natural limitations, or for economic reasons, an ample supply of the water is unavailable. Recooling conserves the water.

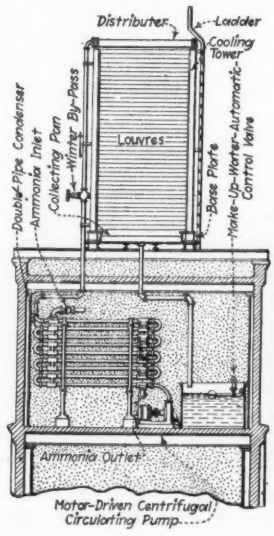


FIG. 1

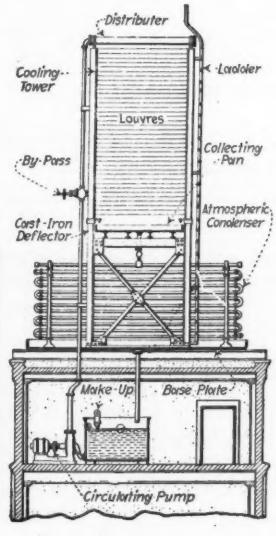


FIG. 2

FIG. 1. METALLIC TOWER FOR COOLING THE WATER FOR DOUBLE-PIPE AMMONIA CONDENSER

FIG. 2. METALLIC TOWER FOR COOLING THE WATER FOR AN ATMOSPHERIC AMMONIA CONDENSER

The cooling effect of cooling ponds, sprays and cooling towers, on condensing water is due to two causes: (1) evaporation of the water, (2) direct heat transfer by conduction and convection, which is of minor consequence as compared to that of the evaporative effect. The cooling effect of evaporation is due to the fact that whenever a liquid evaporates—when it is transformed into a vapor, an amount of heat equivalent to its latent heat of vaporization must be absorbed by it to effect the vaporization. In the atmospheric recooling of condensing water, practically all of this heat which is required to effect the evaporization of the condensing water is abstracted from the unvaporized portion of the condensing water itself. Thereby the remaining portion of the water is cooled. A minor portion of this heat which is required to effect the evaporation is abstracted from adjacent air and objects.

The cooling effect of the direct heat-transfer is usually of minor consequence. This direct-heat-transfer

TABLE I. EXTREME HOT WEATHER HUMIDITIES AND WET AND DRY BULB TEMPERATURES (JULY AVERAGES) FOR DIFFERENT LOCALITIES IN THE UNITED STATES

Locality	Dry-bulb Temp. In Deg. F.	Wet-bulb Temp. In Deg. F.	Relative Humidity In Per Cent.	Wind Velocity Miles Per Hour
Mobile, Ala.	80.5	75.5	79.0	6.0
Phoenix, Ariz.	90.5	68.5	31.0	---
San Francisco	57.3	54.3	82.0	14.0
Denver, Col.	71.8	57.8	45.0	7.5
Washington, D.C.	76.8	69.3	69.0	5.3
Portland, Me.	68.0	62.0	71.0	---
Key West, Fla.	83.7	76.7	73.0	8.0
Detroit, Mich.	72.1	65.1	69.0	9.0
El Paso, Tex.	80.5	64.5	44.0	9.7
St. Louis, Mo.	79.1	70.6	66.0	8.2
Helena, Mont.	66.9	53.4	43.0	---
New York City	73.5	67.0	71.0	9.1
Seattle, Wash.	63.5	56.3	64.0	5.5
Cincinnati, Ohio	77.7	68.7	63.0	6.6
Duluth, Minn.	66.0	60.0	71.0	11.0
Boston, Mass.	71.3	64.8	70.0	9.3

* This material constitutes a portion of the author's forthcoming book, "Steam Power Plant Auxiliaries and Accessories." It is copyrighted by the author and all rights are reserved.

cooling effect is caused by the heat in the condensing water being conducted and radiated into the surrounding air and objects.

Atmospheric Recooling

Atmospheric recooling of condensing-water, after the water has been discharged from the condensers, may be promoted by bringing the water into intimate contact

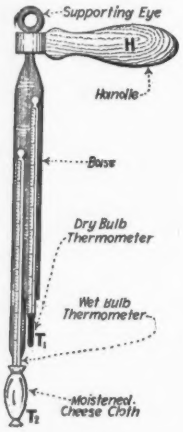


FIG. 3. SLING PSYCHROMETER

with the air of the atmosphere and by the evaporation of a part of the water. Intimacy of contact with the air and ample surface to promote effective evaporation is secured by breaking up the mass of water into a fine spray or into a multitude of tiny streams or rivulets or by spreading it out over an extensive area in a shallow pond. The recooling effect depends upon: (1) the temperature-difference between the water and the air; (2) the relative humidity of the air; (3) the degree of contact-intimacy. High humidity and high-air temperatures are inimical to satisfactory recooling.

Profitable operation of an atmospheric recooling system is, in general, mainly dependent upon the degree of effectiveness with which all parts of the water are brought into contact with the air.

Modern-type steam-condensers ordinarily operate with vacua ranging from about 26 in. to 28 in. of mercury column. Assuming the temperature of the water entering the condenser to be about 85 deg. F., the discharge temperature, corresponding to the vacua above noted, would range from about 90 to 110 deg. F.

The temperature of the water leaving an ammonia condenser (Figs. 1 and 2) of the submerged type may be from about 75 to 80 deg. F., while the water from

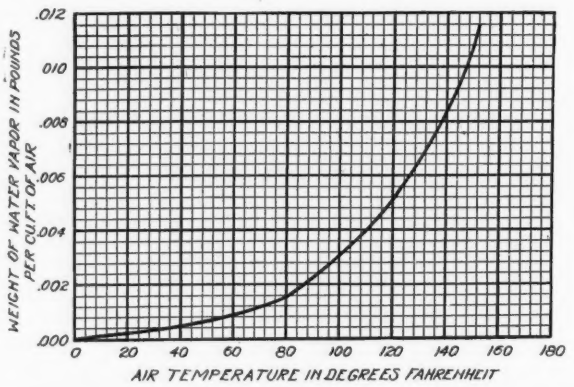


FIG. 4. CURVE SHOWING RELATION BETWEEN TEMPERATURE AND WEIGHT OF WATER VAPOR IN 1 CU. FT. OF AIR OF 100 PER CENT RELATIVE HUMIDITY

an atmospheric ammonia-condenser may, during the summer months, have a temperature of from about 75 to 85 deg. F.

The temperature and relative humidity of the atmospheric air as shown in Table I are dependent upon the locality and the season of the year. For practical purposes, the local weather bureau reports may be referred to for this information. But where these are not obtainable, the relative humidity must be determined by the use of instruments made for the purpose. One such instrument, shown in Fig. 3, is known as a sling psychrometer. This instrument is formed with two ordinary thermometers. The dry bulb of one, T_1 is dry and bare, so as to be exposed directly to the temperature of

TABLE II. RELATIVE HUMIDITIES IN PER CENT CORRESPONDING TO VARIOUS WET AND DRY-BULB TEMPERATURE-DIFFERENCE. (30 IN. BAROMETER.)

Air-Temp. in Deg. F. (Dry Bulb)	Temperature-Difference, In Deg. F. Between Readings Of Wet-and Dry-Bulb Thermometers.																																	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
35	100	91	81	72	63	54	45	36	27	19	10	2																									
40	100	92	83	75	68	60	52	45	37	29	22	15	7	0																							
45	100	93	86	78	71	64	57	51	44	38	31	25	18	12	6																						
50	100	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5	0																			
55	100	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	14	9	5	0																	
60	100	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1															
65	100	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2													
70	100	95	90	86	81	77	73	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3											
75	100	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1								
80	100	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15	12	10	7	5	3	0					
90	100	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5	3	1
100	100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13	12	10

the air. The wet bulb of the other, T_2, is covered with cotton gauze or cloth which is saturated with water.

If air is blown over the two thermometers, or if they are swung by rotating the handle, H, rapidly through the air, the one having the wet bulb will generally show a lower reading than the one with the dry bulb. This is due to the fact that, in general, atmospheric air is not fully saturated. It will still have some capacity for absorption of moisture. Therefore it will absorb moisture from the wet gauze which envelops the wet bulb. A cooling effect, due to evaporation of the moisture in the gauze, is thereby produced.

The relative humidity of the air is a function of the temperature-difference indicated by the wet- and dry-bulb thermometers of a sling psychrometer. Hence, when the temperature-difference shown thereby is known, the corresponding relative humidity may be computed therefrom. Or it may be obtained directly from the results of such computations, which are given in Table II. How these relative-humidity values are utilized in practical computations will be hereinafter explained.

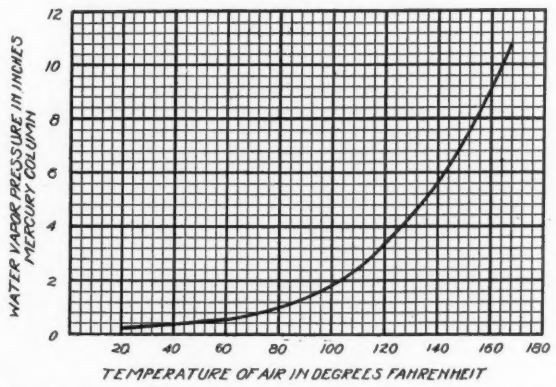


FIG. 5. SHOWING RELATION BETWEEN TEMPERATURE AND VAPOR PRESSURE OF SATURATED WATER VAPOR

When there is no difference between the readings of the wet-and dry-bulb thermometers then the air is fully saturated with moisture. That is, the air has absorbed as much water as it can possibly retain, at the given temperature, in a vaporous condition. Hence, no cooling effect, due to evaporation from the wet bulb, can result. The relative humidity is then 100 per cent.

Suppose, however, the dry-bulb thermometer reads 70 deg. F., and the wet-bulb thermometer reads 60 deg. F.; the temperature-difference then = 70 — 60 = 10 deg. F. The corresponding relative humidity, from Table II, is 55 per cent. This value is found in the same horizontal column with the given value, 70, of the air-temperature, and in the same vertical column with the computed value, 10, of the temperature-difference.

The limit of atmospheric cooling is the wet-bulb thermometer temperature. Careful investigation proves that this is the lowest temperature attainable by cooling in free contact with the atmosphere. This temperature is, then, a measure of the efficiency of any atmospheric-cooling device. Perfect apparatus, that having an efficiency of 100 per cent would reduce the temperature of the cooled water to that of the wet bulb. The number of degrees temperature decrease thus effected would be the ideal range. The number of degrees temperature decrease attained in practice is the actual range. Hence: actual range ÷ ideal range = efficiency of the apparatus, or the percentage of the ideal which is actually realized.

The wet-bulb temperature, therefore, bears the same relation to atmospheric cooling that the barometric height does to condenser vacuums. It is the ideal minimum temperature which can be approached infinitely close but which can never be passed. How nearly this ideal minimum temperature may be attained is determined by: (1) water distribution; (2) cooling surface; (3) air supply. Increasing the effectiveness of any or all of these elements increases the first cost, operating expense, and maintenance expense. There is then, a certain degree of attainment toward the ideal minimum which it does not pay in dollars and cents to pass. The determination of this "point of maximum economic effectiveness' is a problem for specialists.

Efficiency of an Atmospheric Cooling Device

The efficiency of any atmospheric cooling device, cooling pond, spray nozzle installation or cooling tower may be computed by the following formula:

$$E = 100\ (T_{t_1} - T_{t_2} \div T_{t_1} - T_{t_w})$$

Wherein E = the efficiency, in per cent, T_{t_1} = the temperature, in deg. F., of the water coming to the cooling device. T_{t_2} = the temperature, in deg. F., of the cooled water leaving the device. T_{t_w} = the wet-bulb temperature of the surrounding atmosphere in deg. F., corresponding to the given relative humidity, as computed from Table II.

To illustrate the use of this formula, suppose we have a cooling tower with water entering at a temperature of 108 deg. F. while the temperature of the water leaving the tower is 88 deg. F. The temperature and relative humidity of the outside air are, respectively, 70 deg. and 50 per cent. What is the efficiency of the tower? By Table II, the difference between a dry-bulb temperature of 70 deg. F. and the corresponding wet-bulb temperature, for 51 per cent relative humidity, is 11 deg. F., while the difference for 48 per cent relative humidity is 12 deg. F. Therefore, the wet-bulb temperature corresponding to 50 per cent relative humidity = 70 — $\{11 + [(12 - 11) \div (51 - 48)]\}$ = 68.7 deg. F. Then, by Formula (1), the efficiency of the tower = E = 100 $[(T_{t_1} - T_{t_2}) \div (T_{t_1} - T_{t_w})]$ = 100 × [(108 — 88) ÷ (108 — 68.7)] = 51 per cent.

The weight of water vapor which is contained in a cubic foot of atmospheric air is determined by the temperature and the relative humidity of the air. The graph of Fig. 4 indicates the relation between temperature and weight for air of 100 per cent relative humidity. To obtain the weight at any relative humidity other than 100 per cent, multiply the value taken from the graph by the known relative humidity, expressed decimally.

When air is "saturated" its relative humidity is then 100 per cent and the weight of water-vapor content in it is a maximum. Hence, for saturated air, the weight of its water-vapor content is determined solely by the temperature. Likewise, assuming any constant relative humidity, the weight of the water-vapor content will be determined solely by the temperature.

The water-vapor pressure exerted by water vapor in air is determined by its temperature and by the relative

humidity. Water vapor pressure values are used in computing the effectiveness of cooling ponds and towers and similar condensing-water-cooling arrangements. The graph of Fig. 5 shows the relation between temperature and vapor pressure for saturated-air water vapor, that is, for the water vapor in air which is 100 per cent humidity. To obtain the water-vapor pressure exerted by vapor in unsaturated air, multiply the pressure value shown in Fig. 5 which corresponds to the known temperature, by the relative humidity, expressed decimally.

Methods of Air Cooling Available

Three principal devices for bringing the water and air into intimate contact in a recooling system are commonly available. These are: (1) the simple cooling pond or tank, Fig. 6; (2) the spray fountain, Fig. 7; (3) the cooling tower, Fig. 8. Each of these devices has its particular field of application, as will be shown.

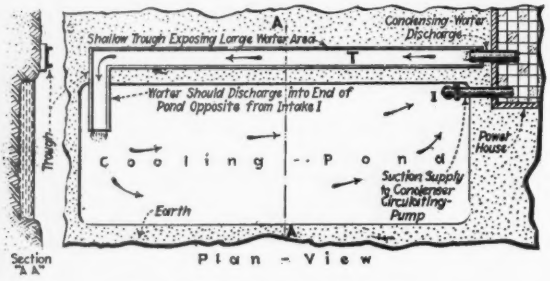


FIG. 6. TYPICAL COOLING POND

Cooling Ponds

Cooling ponds may satisfy the requirements of a recooling system where ample ground space is available. The operation-expense of a simple cooling pond is very low. The power-cost may be, and often is, practically zero. Generally, however, for plants exceeding about 1000 hp. capacity, the area and investment necessary for an adequate cooling pond would be so extensive that the annual cost of the pond would be prohibitive. Hence, for the larger plants, more compact devices, as spray fountains and cooling-towers, may be more economical and satisfactory.

The rate of evaporation from a simple cooling pond, when the air is perfectly calm, may be computed by the following formula.

$$(2) \qquad W = (243 \div 3.7\ T_t)\ (P_v - P_vM)$$

Wherein W = the weight of water evaporated, under calm air, in grains per square foot per hour; it may be increased materially by the effect of wind. T_t = the temperature of the water, in deg. F. P_v = the vapor pressure, in inches of mercury-column, as taken from the graph, Fig. 5, for saturated air at the given temperature. M = the per cent, expressed decimally, of the relative humidity of the air, as found in Table I.

In the expression $(P_v - P_vM)$ in the above equation, P_v is the vapor pressure which would be exerted by a saturated-air vapor at a given temperature and P_vM is the vapor pressure actually exerted by the non-saturated air vapor under consideration. Their difference is a measure of the tendency to promote evaporation.

In practice, the weight of the evaporation may, due to normal wind velocities, be from 2 to 12 times greater than the value obtained by the preceding formula. A fair average is from 6 to 8 times the computed value.

Formula (2) may be rewritten as follows:

$$(3) \qquad W_w = \frac{(243 + 3.7\ T_t)\ (P_v - P_vM)}{7000}$$

Wherein W_w = weight of water evaporated, under calm air, in pounds per square foot per hour. T_t, P_v and M are as given in formula (2).

Suppose the temperature of the water in a cooling pond is 80 deg. F. and the air-temperature also 80 deg. F. The relative humidity is 75 per cent. Assuming that the prevailing wind velocity multiplies, 8 times, the rate of evaporation under calm air conditions, what is the approximate rate of evaporation, in pounds per square foot per hour and how many square feet of the pond surface are required to give off each pound of the evaporation? The graph shown in Fig. 5 shows the water vapor pressure corresponding to a temperature of 80 deg. F. = 1.0 in. of mercury-column. By Formula 2

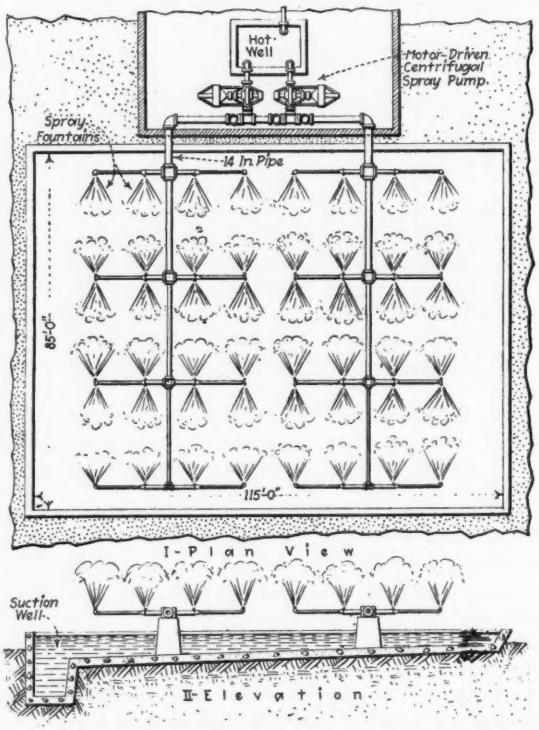


FIG. 7. DOUBLE SPRAYING SYSTEM. IN WINTER ONE SIDE IS SHUT DOWN

the rate of evaporation in calm air = $W = (243 + 3.7\ T_t)\ (P_v - P_vM) = (243 + 3.7 \times 80) \times [1 - (1 \times 0.75)] = 134.75$ grains per sq. ft. per hr. The avoirdupois pound contains 7000 grains. For the prevailing wind velocity, the approximate rate of evaporation = $(134.75 \times 8) \div 7000 = 0.154$ lb. per sq. ft. per hr. Therefore, $1 \div 0.154 = 6.49$ sq. ft. per lb. per hr. = number of square feet of pond surface necessary to evaporate 1 lb. of water per hour.

The evaporation of one pound (1 lb.) of condensing water is equivalent to the abstraction of about 1000 B.t.u. from the water. This is true because, as shown in any steam table, the latent heat of vaporization of water

vapor is, for the vapor pressures encountered in cooling-pond, spray nozzle and cooling-tower practice, about 1000 B.t.u. The approximate vapor pressure in any instance is that, as taken from the graph in Fig. 5, corresponding to the existing air temperature. The exact vapor pressure is that taken from Fig. 5 for the given air temperature, multiplied by the relative humidity.

With low air-temperatures, radiation of heat from the pond and transfer of heat to the air by conduction and convection, assist, to some extent, in cooling the water. The loss of heat by evaporation may, under this condition, be somewhat reduced. With high air-temperatures, the reverse is true. It is generally observed that, in moderately-warm weather and under ordinary conditions, approximately 90 per cent of the cooling effect is due to evaporation and 10 per cent to other causes.

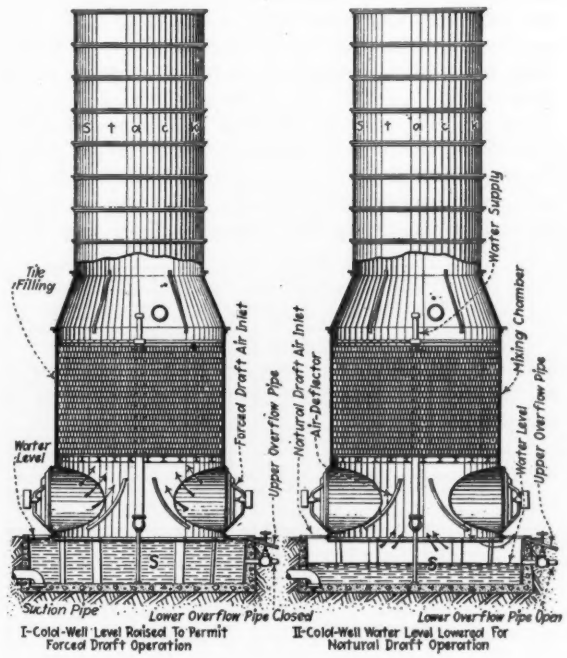


FIG. 8. COOLING TOWER

In estimating the requisite surface area for a simple cooling pond, for cooling the circulating water of a steam condenser, it may, safely, be assumed that: (1) The total heat given up or lost by cooling-pond water is solely that abstracted from the water by evaporation. (2) The total heat imparted to the water is the heat given thereto in the condenser by the steam during its condensation therein. Hence, if the temperature of the condensing water in the pond is to be maintained constant, the pond area must be sufficiently great that it will, by its evaporative effect, release the same amount of heat per hour as is imparted to it per hour by the condensing steam. Now, it may also be assumed that the heat, in B.t.u., which is given up to the condensing water by 1 lb. of steam when the steam is condensed, is equal to the heat in B.t.u. which is abstracted from the cooling-pond water by 1 lb. of the water when it evaporates. In both cases, the amount of heat is about 1000 B.t.u.

Therefore, if the area which is required to give off 1 lb. of evaporation per hour is multiplied by the number of pounds of steam which is condensed per hour, the approximate requisite total pond-area will result.

The foregoing assumptions are not strictly accurate, but inasmuch as the resulting values which are obtained by using formulas 2 and 3 must be increased by from 2 to 12 times to correct for wind effect, the above indicated method is sufficiently accurate for estimating.

The cooling effect of the "make-up" water may be disregarded because the make-up water—that which must be replenished because of evaporation, windage and other losses is less than 2 to 3 per cent of the total amount of water which is circulated. The variation in evaporative effect due to wind will more than offset the cooling effect of the make-up water.

The requisite area for a simple cooling pond cannot in any case be computed precisely, due to the numerous variables which are involved. The most important of these are the temperature and humidity of the air, and, particularly, the wind-velocity. The type of condenser and the kind of condenser-service, whether steam or ammonia, may also affect the problem.

Some Cooling-Pond-Area Data

It has been determined (Proceedings A. S. M. E., April, 1912), that in the northern part of the United States, 120 sq. ft. of cooling-pond surface will suffice for 1 hp. of steam-condenser service. This value is based upon a 26-in. vacuum and a steam consumption of 15 lb. per hp. per hr. Cooling-pond area is sometimes determined upon the assumption that 8 sq. ft. will suffice for each pound of steam condensed; also, that 1 sq. ft. of pond area will give off 4 B.t.u. per hour per deg. F. difference between the water and air temperature in summer, and 2 B.t.u. in winter.

The depth of simple cooling-ponds is usually from 3 to 4 ft. The depth has little influence on cooling effectiveness, provided the surface-area is ample, since the cooling is determined almost wholly by the surface area which is exposed to the air and from which evaporation can take place.

Isn't He the Tease?

It was at the power house. The discussion for the noon hour was "Shocks that I have received," and the cause. Many told some weird experiences. Murphy was out of tobacco, refusing to take part until he could run to the corner grocery for his favorite brand. Behind a smoke screen he returned, grinning.

"Well, Murphy, what's the greatest shock you ever received?"

"Ninety-three thousand volts."

"You mean to say that you were shocked by that and are still alive?"

"I do."

"Say, tell that to the marines? No man ever came in contact with that and got away."

"Who said I came in contact?"

"Then how in hell did you get shocked?"

(With a chuckle). "Oh, the mere mention of it was sufficient." J. B. Dillon.

Don't expect poor work now to lead to brilliant work hereafter.—Forbes Magazine.

Records of Flue Gas Analyses with Fuel Oil

CALCULATION OF FUEL LOSSES FROM FLUE GAS ANALYSES AND MOISTURE CONTENTS OF FUEL AND AIR. BY L. J. GOODRICH

FLUE GAS is analyzed to determine the conditions of combustion of the fuel and to procure data for apportioning the heat losses. The quantity heat (B.t.u.) lost per pound of fuel oil burned through incomplete combustion of carbon and the presence of (CO) in the flue gas is in (B.t.u.) obtained by using the formula: $L = 10.150 \times (CO - CO_2)\ C$, where CO and CO_2 are the percentage of the gases by volume in the flue gases and C is the percentage of C by weight in the fuel.

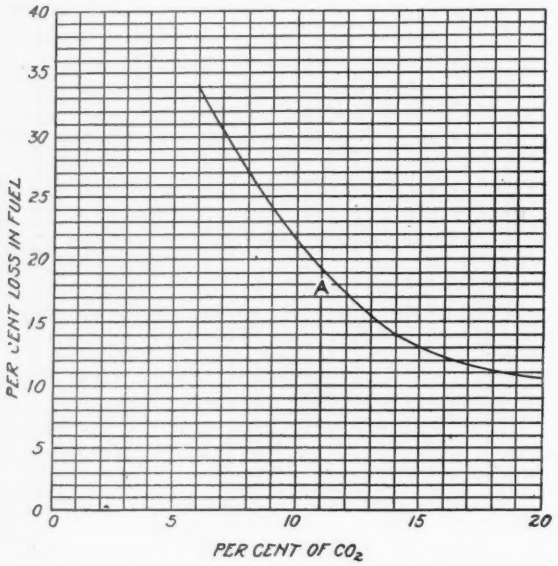


FIG. 1. FUEL LOSSES AS INDICATED BY PERCENTAGE OF CO_2 IN FLUE GASES

Loss of heat due to utilization of a portion of the heat of the fuel in evaporating the moisture contained in it after raising it from atmospheric temperature to 212 deg. F., and superheating it to the temperature of the flue gases, in B.t.u. per pound of combustible, may be calculated from the formula:

$$\text{Loss} = w(1090.6 - T_0 + 0.46\ T_1)$$

Where W = moisture per pound of fuel in pounds.
T_0 = temperature of boiler room in degrees F.
T_1 = temperature of flue gases in degrees F.

The loss of heat through the superheating of moisture in the air, the loss being expressed as B.t.u. per pound of fuel equals $0.47M\ (T_1 - T_0)$.

Where M = weight of moisture introduced with air.
T_0 = atmospheric temperature.
T_1 = stack temperature.

The loss due to hydrogen in the fuel, the loss being expressed as B.t.u. per pound of combustible equals:

$$9H\ (1090.6 - T_0 + 0.47\ T_1)$$

Where H = weight of hydrogen per pound of combustible.
T_1 = stack temperature in degrees F.
T_0 = atmospheric temperature in degrees F.

From above formulas it is possible to compute the distribution and amount of the heat losses. The heat used by the boiler can be computed from the knowledge of the amount of water evaporated and the conditions under which this is done. The steam tables will be of assistance in doing this. Various recording CO_2 meters are in use and if occasionally checked by an Orsat apparatus are invaluable in the proper operation of a plant. CO_2 readings alone are not sufficient without these supplementary readings.

Many plants upon the installation of meters have begun the bonus system of firing, contingent upon a minimum CO_2 reading for proper operating conditions. The flat rate is paid upon this and a bonus is awarded for any further saving obtained by the fireman.

To burn fuel with the greatest efficiency, it must be burned with just enough air to make complete combustion possible. Too much air unnecessarily increases the volume of flue gases which must be heated and any excess in their volume increases the heat carried away by them accordingly. Too little air on the other hand results in incomplete combustion. Unburned combustible gases then escape up the chimney. Since they have a heating value often exceeding that of illuminating gas, it is clear that the heat losses due to incomplete combustion may be more serious than those due to too much air.

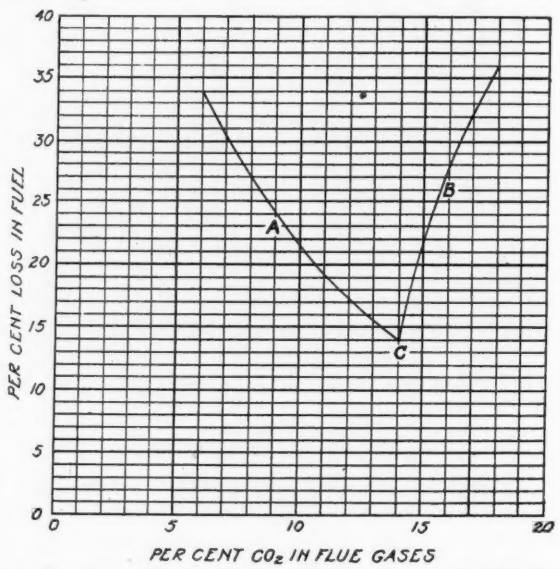


FIG. 2. RELATION OF FUEL LOSS TO CO_2 UNDER ASSUMED CONDITIONS WHEN COMBUSTIBLE GASES ARE FORMED

It is found in practice that to obtain the most economical results a certain surplus of air is necessary above what would be theoretically correct. The amount of this surplus varies, depending on the many different factors that affect combustion. In any case, however, the point at which most economical combustion takes place is that point beyond which an increase in the air supply results in excessive volumes of flue gases, while reduction in the air supply results in incomplete combustion. This is the critical point.

Heretofore the control of combustion in boiler plants usually depended only on the recording of the percentage of CO_2 present in the products of combustion. While the recording of CO_2 indicates surplus of air in the flue gases it does not indicate when incomplete combustion due to insufficient air is taking place. The introduction of the duplex gas recording meters marks a tremendous stride in advance in the combustion control field. Since this apparatus indicates exactly to what degree economical combustion is being attained by measuring and recording at all times not only the waste due to excess air, but also that due to unconsumed combustible gases going up the chimney. We have here an epoch making development in the march of progress toward ideal economy in the use of fuel.

The great importance of recording both the excess of the air (CO_2) and the percentage of combustible gases (CO, CH_4, H_2), and doing this simultaneously, is clearly demonstrated in the two curves, Figs. 1 and 2, which represent the relation between percentage of chimney losses and percentage of carbon dioxide in flue gases. With the decrease in air supply (increase in CO_2), the chimney losses diminish, consequently it would appear that the most economical results will be obtained when the percentage of CO_2 is as high as possible. But this is not true, because combustible gases are bound to form when CO_2 reaches a certain point on the curve. The position of this point varies considerably. It is the critical point where combustion takes place with the greatest economy in fuel consumption.

Figure 2 shows the same curve as Fig. 1 up to where the percentage of CO_2 is 14. Let us assume that at this point combustible gases begin to appear as is often the case. Under these conditions, the point where CO_2 is 14 per cent, is the point of most economical combustion. It is the critical point. The unavoidable loss at this point is 15.3 per cent of the total fuel used. Using average values, let us figure that one per cent of combustible gases forms for every per cent increase in CO_2 beyond the critical point mentioned. Calculations taking into account the heating value of the combustible gases will then show that should CO_2 reach 15 per cent, the fuel loss would jump up to 22 per cent, and with 16 per cent CO_2 the loss in fuel would reach 28 per cent. It is evident that the critical point of economical combustion is the point where incomplete combustion sets in with a decrease of air supply. It must always be borne in mind that it will vary with the load factor, fuel, heat value and uniformity of fire, distribution of air supply, draft, soot, etc. Only by simultaneously and continuously recording both excess air and combustible gases (CO_2 and CO, CH_4, H_2) can this critical point be known at all times. From the foregoing, it is evident that incomplete combustion is a prolific cause of important losses. A duplex gas recording apparatus makes it possible to visualize in the form of a continuous record just when incomplete combustion is taking place. This type of apparatus will record whenever incomplete combustion is prevalent to a far greater degree than was ever suspected, even under the most favorable conditions. In the effort to promote economical combustion by reducing the air supply, the great danger of running into wasteful combustion due to incomplete combustion is ever present. That is why the recording of CO_2 alone has never given results even approaching the possibilities which, as is positively known, can be realized in the economical combustion of fuels.

Why Pick on Acetylene?

ONE DOES not read much of the danger of air and water as explosive agents. Of course, when a boiler explodes the water has been converted into steam; but just simple, everyday water, the kind that comes from the well or the bathroom faucet, is explosive under certain conditions. So is air explosive under the same conditions; unfortunately those conditions obtain under circumstances in which they are not always apparent. They, the conditions, are: confinement and application of heat in sufficient degree for the expansion to burst the confining walls. An example of an explosion of this kind in which acetylene was not used at all, was the explosion recently in a New York welding shop where, because oxy-acetylene apparatus was a part of the plant equipment, the news-sleuths deduced another "acetylene explosion." It was not reported in one, but in all of the New York City dailies as an explosion of acetylene.

The facts were these: An automobile tubular drive shaft was placed in the fire of an ordinary blacksmith's forge for heating preparatory to straightening the tube. Unknown to the workmen, the tube contained confined air. Had there been so much as a pinhole, the expanding air might have escaped without violence. It would have been a very simple matter to tap the tube with a drill. This precaution was not taken merely because the air inclusion was not obvious. The result was an explosion that sent several workmen to the hospital to be treated for burns sustained from the flying embers from the forge. No damage was done to the shop, but the force of the bursting tube and released air was sufficient to endanger the lives of the workmen.

Quite similarly, the other day a workman engaged in welding a hollow metal ball about 3 in. in diameter, did not know that the ball was filled with water; why it was so filled is still a mystery; but the water expanded under the heat of the welder's flame, bursting the shell of the ball and exploding like a bomb. Fortunately the workman was not killed, and was thus permitted to learn by experience what all the rules of caution ever put into print could not teach him so thoroughly. It is safe to wager he will never again "take a chance" welding any hollow metal without first tapping it to vent whatever it contains. This also was served up to newspaper readers as an oxy-acetylene explosion. Of course it was nothing of the kind; but by the time the facts were ascertained the story ceased to be news, so it goes unretracted as just another of those acetylene explosions!

A little knowledge, a little horse sense and the caution these beget ought to go a long way toward eliminating the types of accidental explosion just noted.

AS THE result of experience gained on the Santa Fe system, it is stated that the life of a boiler fired with coal is about 10 per cent greater than that of one fired with oil, while the life of the tube is about 40 per cent higher in the coal burners.—Mechanical Engineering.

Properties and Characteristics of Colloidal Fuel

ABSTRACTS OF PAPERS READ BY LINDON W. BATES AND HAYLETT O'NEILL BEFORE THE ROYAL SOCIETY OF ARTS, LONDON

COLLOIDAL FUEL as defined by Mr. Bates, the originator of the term, for the Century Dictionary, is this: "A stable, mobile, atomizable fuel displaying colloidal characteristics, comprising particles of solids, droplets of liquid or minute bubbles of gases, or combinations thereof, suspended in one or more varieties of liquid hydrocarbons."

The object of combining solid and liquid fuel is to utilize the cheaper heating values of the solid variety and yet retain the recognized fluid advantages of the oils. The result is that the value of the carbon is increased without decreasing the value of the liquid.

Where tars and tar products are less expensive per unit of heating value than oils, and have the desired viscosity characteristics, they may be used in combination with oil and coal. Experiments show that in some instances certain tar products may even serve as the principal fluid component.

The solid component may be coal, coke, charcoal, lignite, peat, hard pitch or any grindable carboniferous material. The amount of non-combustible matter in the solid component, within limits, has little effect on the combustion efficiency. The principal objection to such inert matter is the cost of storing and handling unproductive material.

Colloidal fuel is composed of from zero to 40 per cent of carboniferous material mixed with fuel oil and held in suspension with about one per cent of fixateur (not 10 per cent as stated in the Jan. 1 issue of Power Plant Engineering). The mobile pastes and gels can contain much more coal. Table I shows the characteristics of colloidal fuel for various percentages of its components.

The specific gravity of this fuel is always greater than that of the base oil and for commercial limits is greater than that of water. In general the specific gravity can be found from the equation:

Sp.Gr.= (100 × sp. gr. of coal × sp. gr. of oil) ÷ (per cent oil × sp. gr. of coal + per cent coal × sp. gr. of oil.)

Where there are more components, the equation becomes:

Sp.Gr.= (100 × sp. gr. coal × sp. gr. oil × sp. gr. tar) ÷ (per cent coal × sp. gr. oil × sp. gr. tar + per cent tar × sp. gr. coal × sp. gr. oil + per cent oil × sp. gr. coal × sp. gr. tar.)

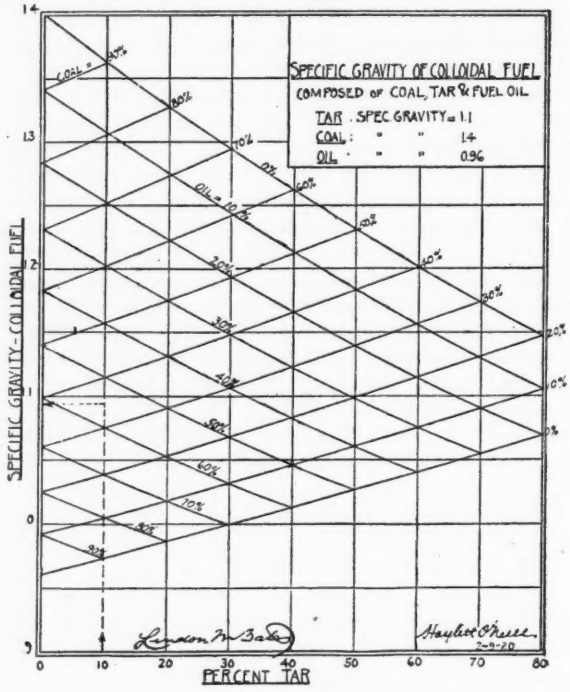

SPECIFIC GRAVITY OF COLLOIDAL FUEL
COMPOSED OF COAL, TAR & FUEL OIL
TAR . SPEC. GRAVITY = 1.1
COAL : " " 1.4
OIL " " 0.96
SPECIFIC GRAVITY - COLLOIDAL FUEL
PERCENT TAR
Lindon W. Bates
Haylett O'Neill
2-9-20

FIG. 1. SPECIFIC GRAVITY OF COLLOIDAL FUEL, OIL, TAR, AND COAL

Figure 1 is a chart showing the specific gravity of colloidal fuel for various compositions of oil, coal, and tar. The heating value of colloidal fuel, B.t.u. per pound, is: H = (per cent coal × B.t.u. per lb. coal + per cent oil × B.t.u. per lb. oil) ÷ 100. Figure 2 gives

TABLE I. COLLOIDAL FUEL COMPONENTS AND CHARACTERISTICS (TYPICAL EXAMPLES SHOWING PRINCIPAL COMPONENTS IN ROUND NUMBERS ONLY)

Example.	Paraffin Base Oil	Asphaltic Base Oil.	Pressure Still Oil.	Wax Tailings	Coal Tar	Middle Fraction Coal Oils	Road Oils	Anthracite Coal	Bituminous Coal	Coke.	Fuel Specific Gravity	Fuel Flash-point (Open Cup)	Fuel B.Th.U (per lb.).	Viscosity (Degrees Engler). 70°—100° F	Suitable Preheat.	Stability (Minimum at 70° F.)
A	70 %	—	—	—	—	—	—	—	30 %	—	1·03	240° F	17,100	170° E.	150° F.	3 months
B		—	35 %	—	20 %	10 %	—	—	35 %	—	1·12	250°F ±	17,000	350° E.	160° F.	3 months
C	10 %	—	37 %	3 %	—	—	10 %	38 % (25 % ash)	—	—	1·15	300°F +	15,300	200° E.	150° F.	10 days
D	10 %	30 %	30 %	—	—	—	—	—	30 %	—	1·08	266° F	17,200	67° E.	150° F.	4 months
E	8 %	—	50 %	—	10 %	2 %	—	—	30 %	—	1·04	262° F.	16,650	452° E.	180° F.	4 months
F	—	60 %	4 %	—	—	—	—	—	18,%	18 %	1·05	273° F.	16,900	—	180° F.	6 months
G	—	54 %	4 %	—	—	—	—	—	21 %	21 %	1·08	280° F.	16,700	—	180° F.	8 months

the heating value of colloidal fuel for varying percentages of coal in the mixture and Table II gives the relative heat density or relative heating value per unit volume of various industrial fuels. (The chart indicates heating value per imperial gallon which is 6/5 as great as for the U. S. gallon.)

TABLE II. HEAT DENSITY OF VARIOUS FUELS

Fuel.	B.Th.U. per lb.	Cubic Feet per Ton.	B.Th.U. per Cubic Foot.	Relative Heat Density.
Colloidal Fuel	16,675	33·3	1,115,232	100·0
Topped Mexican Oil	18,500	37·5	1,106,300	99·2
Anglo-Persian Oil	18,990	40·3	1,055,000	94·6
Paraffin	19,728	44·2	999,736	89·6
Petrol	19,962	51·6	870,543	78·1
Scotch Coal	13,800	46·2	669,000	60·0
Newcastle Coal	14,300	49·8	645,000	57·8
Welsh Coal	15,000	54·6	615,000	55·1
Pulverized Scotch Coal	15,000	56·0	600,000	53·8
Acetylene Gas	21,850	32,600	1,502	0·0013
Carburetted Water Gas	12,888	41,500	650	0·0006
Hydrogen	61,500	423,000	325	0·0003
Producer Gas	1,929	32,200	134	0·0001

Another advantage of colloidal fuel is its freedom from loss due to evaporation. This fuel is practically non-volatile at storage temperatures according to the report of the Underwriters' laboratories, and moreover, it can be kept under a water seal.

The combustion efficiency of this fuel depends, just as with either oil or coal, on the furnace design, rate of firing, and excess air. The furnace should be of such

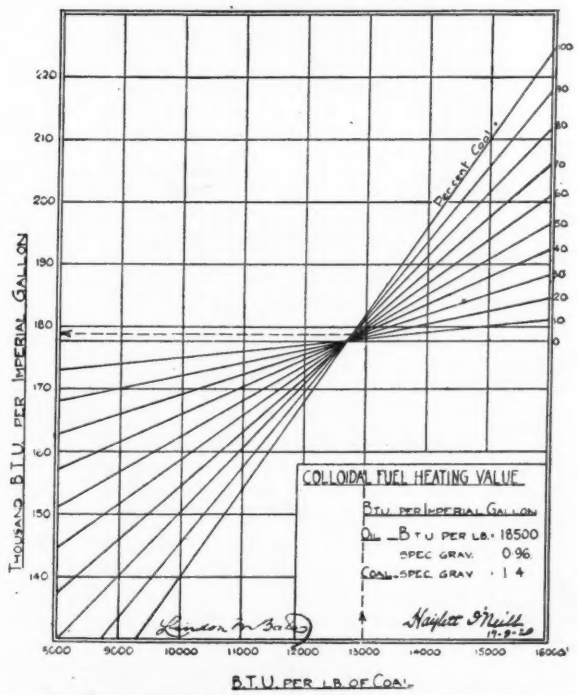


FIG. 2. HEATING VALUE OF COLLOIDAL FUEL PER GALLON (IMP.)

size that there is sufficient distance between the burner and any wall to give the fuel time to be completely consumed before coming in contact with these walls. Excess air can be reduced to that necessary for burning fuel oil. The loss, however, due to heating the moisture formed by the combustion of hydrogen content per unit of fuel is reduced.

Unquestionably the big factor of colloidal fuel economy is the saving in the cost per given number of heat units over that of straight oil because of the relative cheapness of the coal component.

How Much Can You Afford to Pay for a Soot Cleaner

By W. F. Schaphorst

OFTEN, these days, engineering problems are figured on a capitalization value basis. For example, one engineer figured the "capitalization value of a steam leak" and he found it to run up into the thousands of dollars for the smallest leak; that is, the cost of almost any leak represents interest on a comparatively large capital sum.

In the same way, it is well to compute the capitalization value of engineering products such as cleaners for boiler tubes—inside and out—belt dressings, feed water heaters, economizers, forced draft blowers, boiler feed regulators or paint for keeping air from leaking through brick settings into combustion gases thus diluting them and so on. Invariably it is found that these fuel-saving devices are very good paying investments.

As the writer has been doing some computing on soot cleaners of late, a formula was developed to assist the possible purchaser in determining the amount of money he can afford to spend for such a cleaner. The formula is:

$$4\,C\left[\frac{\frac{W}{EH}-42\,N}{\frac{457}{(T-t)}+1}\right]=\text{Value of cleaner}$$

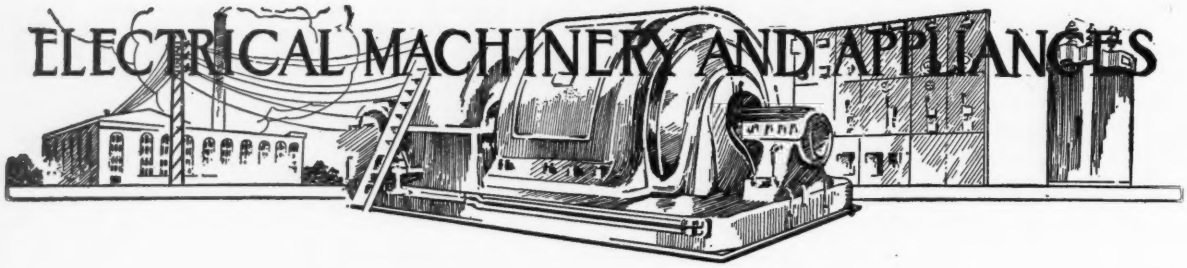
where W = number of tons of coal burned per year; C = cost of coal per ton in dollars; E = boiler efficiency in per cent before installation of soot cleaner; H = heat value of coal in B.t.u. per pound; T = temperature of chimney gases before installation of soot cleaner; t = temperature of chimney gases after installation of soot cleaner; N = number of boilers in use.

The result obtained by substituting in this formula could perhaps be properly termed the "capitalization value of a soot cleaner." The formula assumes that the purchaser of the cleaner expects to realize 25 per cent on his money including interest, depreciation and upkeep.

For example, if the annual coal consumption in a given furnace is 10,000 tons of coal per year, boiler efficiency before installation of the cleaner is 70 per cent, temperature decrease (T — t) is 50 deg. F., number of boilers is one, and the cost of the coal is $5 per ton, substitution in this formula will show that the boiler owner can afford to pay $4460 for a cleaner.

In the above formula, it is assumed that 18 lb. of air are used per pound of coal as fired, that there are six elements in an average installation, that the boiler is cleaned four times per day, that the boiler is cleaned and operated 300 days per year and that the average rate of evaporation is 6 lb. of steam per pound of coal.

THE FELLOW who knows it all died in the year one—name unknown.



Alternating Current Instruments

DISCUSSION OF THE THEORY, CONSTRUCTION, AND APPLICATION OF VOLTMETERS, AMMETERS AND WATTHOUR METERS. BY VICTOR H. TODD

IN ALL alternating-current instruments, there will be found three forces at work to make the instruments give an indication on a suitably calibrated dial: (1) the actively energized agent; (2) the agency against which this reacts; and (3) the restraining or controlling agency generally in the form of spiral springs. Damping is not an electrical essential, but a well damped instrument represents the best practice and is indicative of good design and manufacture. As in the direct-current instruments, the moving element is provided with glass-hard highly polished pointed steel pivots which rest in polished jewel bearings in order to reduce friction to a minimum. Great care must be taken in handling the instrument that it is not subjected to

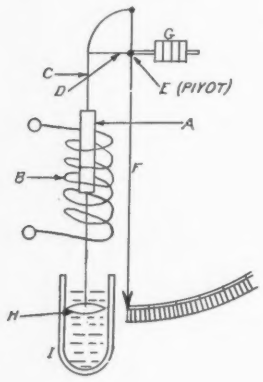


FIG. 1

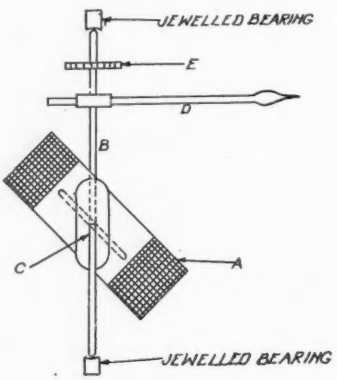


FIG. 3

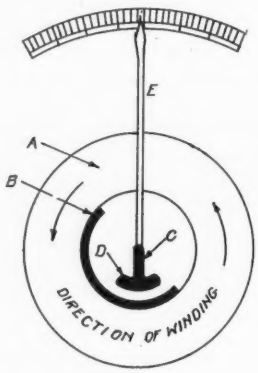


FIG. 4

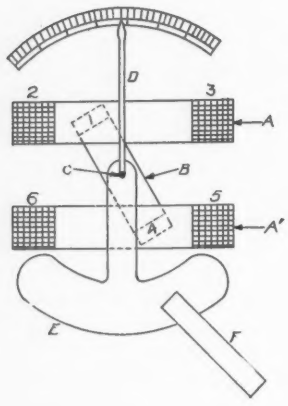


FIG. 5

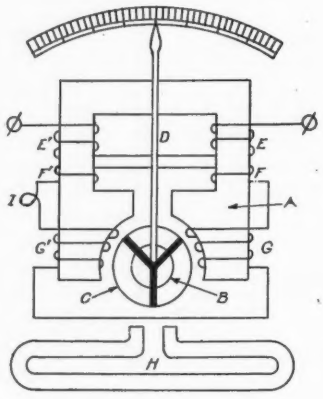


FIG. 8

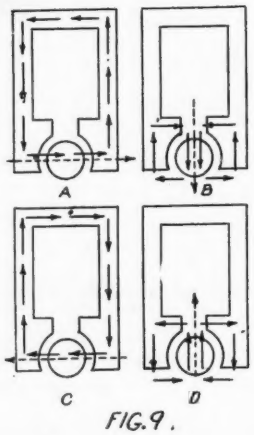


FIG. 9.

FIG. 1. DIAGRAMMATIC SCHEME OF PLUNGER TYPE MOVING IRON INSTRUMENT. FIG. 3. DIAGRAMMATIC SCHEME OF THE INCLINED COIL TYPE. FIG. 4. REPULSION TYPE OF MOVING IRON VANE INSTRUMENT. FIG. 5. DIAGRAMMATIC SCHEME OF DYNAMOMETER PRINCIPLE OF OPERATION. FIG. 8. DIAGRAMMATIC SCHEME OF THE INDUCTION METER. FIG. 9. PATH OF MAGNETISM IN FOUR STEPS. DOTTED ARROW SHOWS THE GENERAL DIRECTION OF MAGNETISM AT EACH QUARTER CYCLE.

sudden jars or excessive shocks which might flatten the pivot ends or shatter the jewel bearings thus rendering the instrument inaccurate or inoperative.

Alternating-current ammeters and voltmeters in commercial use employ the electro-dynamometer, the induction and the moving-iron-vane principles in their operation.

Alternating-current wattmeters employ both the dynamometer and induction principle but the a.c. watthour meters employ the induction principle almost exclusively in their operation. The dynamometer principle as applied to watthour meters is limited almost entirely to direct-current work.

The Moving Iron Vane Principle

The simplest application of this principle is shown in Fig. 1 where A is a soft iron plunger suspended in the wire-wound solenoid B by means of the silk thread, C, which is led over the grooved sector D. This

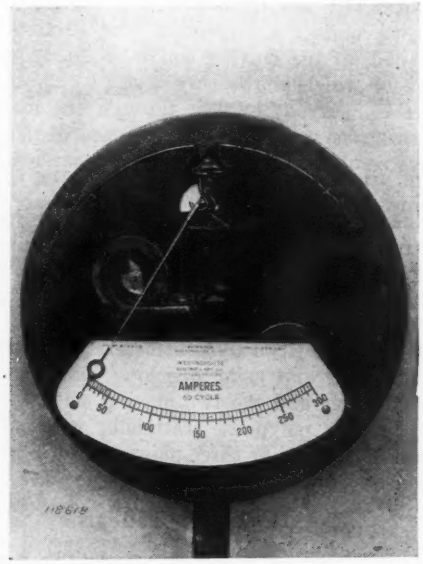


FIG. 2. TYPICAL PLUNGER TYPE INSTRUMENT

sector is pivoted at E, and to it is rigidly attached pointer F and counter-weight G. At the lower end of the plunger is small aluminum disk H, which by working in oil in glass tube I, effectually damps the movement. In this type, coil B is the actively energized agent; plunger A is the reacting agent; counter-weight G the restraining or controlling agent and disk H and tube I form the damping agency.

It will readily be seen that as current flows through the solenoid, it will pull the plunger farther and farther toward its center, causing sector D to rotate and thus produce a deflection over the scale.

In the ammeters, the solenoid is wound with few turns of heavy wire or strap, the number and size depending on the current carried. (About 1000 amp. turns are required.) In the voltmeter, the solenoid is wound with many turns of fine wire and placed in series with an external resistor. A meter of this type is shown in Fig. 2.

Another method of utilizing the moving iron vane is shown in Fig. 3 where A is a coil wound with a few turns of heavy wire for an ammeter and many turns of fine wire for a voltmeter. This coil is inclined on an angle as shown. Pivoted in its center is a shaft B which carries soft iron C and pointer D. Normally, the iron is in the position shown by the dotted lines almost at right angles to the axis of the coil but as current flows

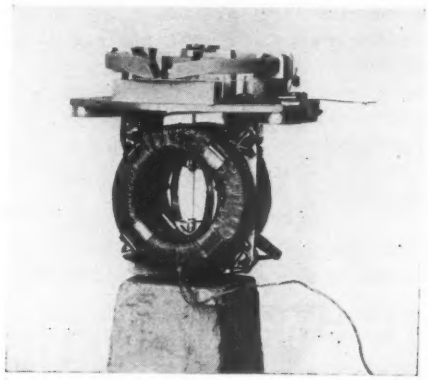


FIG. 6. TYPICAL DYNAMOMETER ELEMENT

through the coil, this iron attempts to aline itself parallel with the axis of the coil and in doing so rotates the shaft thus moving the pointer over the scale and winding up spiral spring E until its restraining effect is equal to the deflecting or turning effort.

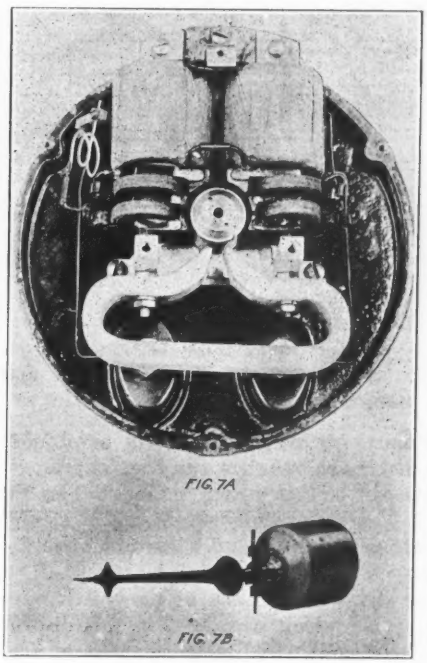


FIG. 7. INDUCTION TYPE MAGNETIC SYSTEM, INTERIOR VIEW WITH MOVABLE ELEMENT REMOVED

Another scheme employed quite extensively is shown diagrammatically in Fig. 4 where A is the main coil wound as before with a large wire for an ammeter and a fine wire for a voltmeter. On the inside of the coil is a fixed iron vane B, tapering and semi-circular in form. Pivoted in the center is staff C to which is rigidly attached iron vane D and pointer E. As the coil becomes

energized, pieces B and D become magnetized with a similar polarity and tend to separate. This separation causes the staff to rotate and causes a deflection of the pointer over the scale.

While the three previously described types are used extensively on a.c. yet with proper calibration they may be used on d.c. Their greatest disadvantage, however, is that the vanes are apt to become polarized or permanently magnetized thus producing considerable error in indication and in the plunger type, a sluggishness which renders them still further inaccurate. Other inherent errors have discouraged their use except where low first cost is of vital importance and accuracy a secondary consideration.

The Dynamometer Type

By far the most satisfactory principle of operation for an accurate ammeter, voltmeter or wattmeter is the

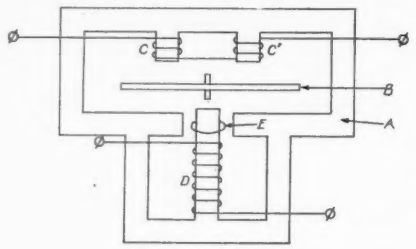


FIG. 10

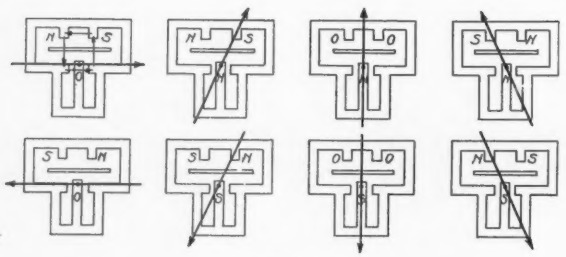


FIG. 11

FIG. 10. SCHEMATIC DIAGRAM OF THE INDUCTION TYPE WATTHOUR METER

FIG. 11. THE ARROW SHOWS THE GENERAL DIRECTION OF MAGNETISM AT EIGHT POINTS OF THE CYCLE

dynamometer principle employing a set of fixed coils and a moving coil as shown in Fig. 5. The general perspective can be seen better in Fig. 6. In Fig. 5, coils A and A′ are stationary while coil B is pivoted at C and carries pointer D and aluminum vane E. Current is conveyed to the moving coil by two small copper conducting strips and motion of the coil is opposed by a spiral spring which is omitted in this drawing for the sake of clearness. The meter operates on the principle that two parallel wires carrying current in the same direction will attract each other but will repel each other when the current is flowing in opposite direction. For instance, if current is flowing down at points 2, 4 and 6, and flowing up at points 1, 3 and 5, then the 1 end of moving coil will be repelled by the 2 side of coil A, but will be attracted by the 3 side. Similarly the 4 side of coil B will be repelled by the 5 side of Coil A′ but will be attracted by the 6 side, thus tending to move the pointer toward the right.

The free oscillations of the pointer are effectually damped out by the aluminum disk, E, passing between the poles of the electromagnet, F. Another make of instrument utilizes a small aluminum vane working in a closed air-box, the damping being accomplished by the compression and rarefication of the air in this little box, due to motion of the vane.

In the voltmeters, both the stationary and the movable coils are wound with a great many turns of fine wire and placed in series with a non-inductive high resistor. Since the resistance of this circuit is fixed, the small current will be directly proportional to the voltage across which it is connected and the meter, by measuring the effect of this small current, can be graduated to indicate the applied voltage. The sensibility of dynamometer type voltmeters varies from about 10 ohms per volt in the 50 or lower voltage ranges to 40 ohms per volt in the ranges of about 750 v.

In the ammeter, the stationary coils are wound with a comparatively few turns of heavy wire, but it is not feasible to conduct a current of 5 or 10 amp. into the moving coil, so the moving coil is shunted by a heavy low resistor which allows only a small definite fraction of the main current to flow through the moving coil. But insofar as the deflection is concerned, this gives the same results as if the moving coil carried the total current.

In the wattmeter, the stationary coils are wound with a few turns of heavy wire and carry the main current while the moving coil is wound with many turns of fine wire and is connected in series with a high resistor across the voltage of the circuit. The polyphase wattmeter is formed by placing two dynamometer type elements one above the other and using one long shaft to carry the pointer, damper and the two moving coils. By proper connection, this polyphase wattmeter will indicate the true watts of a two- or three-phase system regardless of variations in power factor, frequency or wave form.

The Induction Principle

The induction principle is rather difficult to explain without resorting to higher mathematics and vector diagrams and although the reader is asked to accept the following statements as facts, yet it must be borne in mind that each one can be readily proven, both experimentally and mathematically.

A typical magnetic system of an induction type meter is shown in Fig. 8 where A is a set of soft iron laminations of the shape shown, and with laminated core B produces a round gap in which aluminum, cup-shaped drum C is free to revolve. This drum is mounted in jeweled bearings and carries pointer D.

Main winding E and E′ is a few turns of heavy wire in the ammeters and a large number of turns of fine wire in the voltmeters connected in series with a non-inductive resistor. Under this winding is a secondary winding F′ and F which supplies the polepiece winding G and G′. In time, the magnetism produced by these coils is about ¼ of a cycle apart while in space the two magnetisms are at right angles.

Figure 9 shows the four positions of magnetism. In Fig. 9 (a) the magnetism from coils E and E′ is alone active producing a magnetism across the aluminum

drum. In Fig. 9 (b) this magnetism has decreased to zero but the magnetism of the coils G and G′ is active in producing magnetism at right angles to the previous value. In Fig. 9 (c) the magnetism from coils G and G′ has decreased to zero and the magnetism is again across the drum but in the opposite direction to Fig. 9 (a). In Fig. 9 (d), magnetism from coils G is again active in producing magnetism as shown. Although shown in only four positions, it must be understood that there is no sudden jumping of magnetism from one position to another, but a gradual increase of one and a decrease of another, thus resulting in a constantly progressing rotating or sweeping magnetic field.

Thus for each cycle the magnetic field makes a complete sweep of the drum and this sweeping generates small currents in the drum which by reacting on the main magnetism tends to make the drum rotate in the direction of the sweeping field.

In this type, the free oscillations of the moving element are damped out by placing a powerful permanent magnet, H, so that iron core B completes its magnetic circuit and any movement of the drum generates small currents in the drum which quickly absorb the mechanical energy of the oscillations.

Adjustment of Induction Instruments

In this type of ammeter and voltmeter, the scale deflection may be varied by changing the resistance of they do have an external reactor in series with the potential winding, and by varying this reactor, the scale deflection may be adjusted. In the wattmeter there is a winding which is short circuited by a piece of copper wire and this causes the field magnetism to be 90 deg.

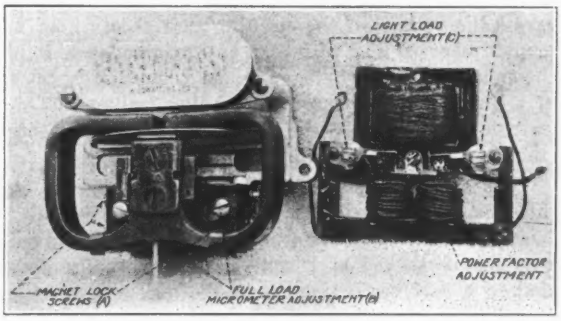


FIG. 13. SHOWING ADJUSTMENTS ON A TYPICAL WATTHOUR METER

in time displacement from the magnetism of the current winding, a condition necessary for the measurement of watts at low power factors.

The Induction Type Watthour Meter

The induction principle finds its greatest application in the watthour meter as there are no brushes or

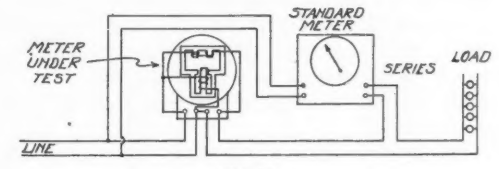
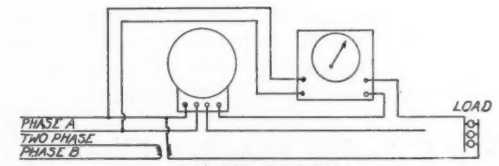


FIG. 12



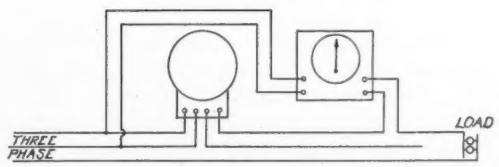


FIG. 14

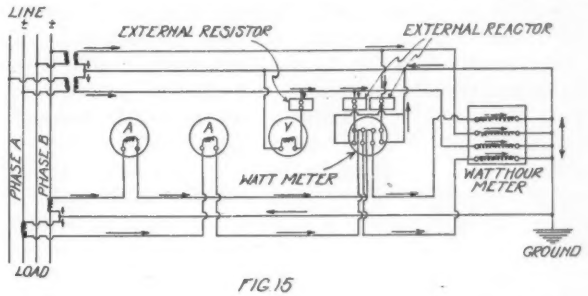


FIG. 15

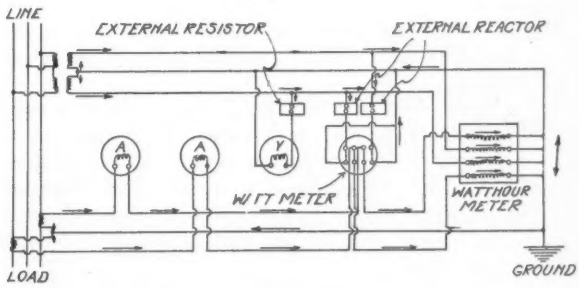


FIG. 16

FIG. 12. CONNECTIONS FOR TESTING A WATTHOUR METER. FIG. 14. METER CONNECTIONS FOR 0 AND 50 PER CENT POWER FACTOR. FIG. 15. METER CONNECTIONS —TWO-PHASE CIRCUIT. FIG. 16. METER CONNECTIONS—THREE-PHASE CIRCUIT

coil I (Fig. 8) which is in series with the secondary and polepiece winding. Adding more wire or increasing the resistance will increase the scale deflection. This adjustment should be used merely to correct inaccuracies of several per cent but not to change full scale rating of the instrument. To change this, a new control spring should be obtained. In the voltmeters, an additional adjustment is had by varying the external resistance.

Wattmeters do not have this secondary winding but commutator or conducting strips to introduce friction at light loads. The question is often asked, "What makes the disk go around when nothing touches it?" and yet in spite of its simplicity of construction, the explanation is generally vague and incompletely understood by the average person. This is especially true of explanations showing how currents are induced in the disk and how these react on the main currents to produce rotation.

Perhaps the simplest explanation is to consider the shifting field as an invisible gear wheel meshing magnetically with the edge of the disk. Consider Fig. 10. Iron punchings A produce three poles and an air gap in which aluminum disk B is free to revolve. Coils C and C′ carry the main current while coil D is connected across the voltage of the circuit. Coil D is wound with many turns of fine wire and as its impedance is high the current and magnetism in pole I lags almost 90 deg. or a quarter cycle behind the applied voltage. This is brought exactly to 90 deg. by a short-circuited copper stamping E over the end of the pole.

The shifting field can be best shown in the eight different positions in Fig. 11, and it can readily be imagined that this shifting field is like a small invisible gear wheel pivoted at F and meshing with the disk so that as it revolves it also causes the disk to revolve. In these figures, just imagine the arrow as sticking through the disk and as the arrow shifts, it carries the disk with it.

Adjustment of the Watthour Meter

In the actual meter there are usually three separate adjustments to be made; light load, full load, and power factor. The meter under test is first connected up with a standard rotating watthour meter with the current coils in series and the potential coils in parallel as shown in Fig. 12. Full load is applied to both meters for about one minute and it is noted whether the meter under test runs faster or slower than the standard. If faster, screws A in Fig. 13 are loosened and then screws B turned slightly to cause the permanent magnets to move outward. Or if the meter ran slower, the magnets are moved in. When correct on full load, about 2 or 4 per cent load is applied to the meter and screws C are adjusted to cause the meter to register correctly on light load. There is usually a small arrow on these screws telling which way to turn to make the meter fast or slow. Care must be taken that both screws are adjusted equally or the meter will creep on potential alone. To test this, throw off the load and adjust either screw until the disk stands still on potential only. Then retest on light load.

Testing on low power factor is best done on a two-phase circuit if correct registration is desired on 0 power factor or on three-phase if correct registration is desired on 50 per cent power factor. The diagrams in Fig. 14 show how 0 power factor is obtained on a two-phase circuit and 50 per cent power factor on a three-phase circuit.

The polyphase watthour meter consisted of two separate elements with both disks mounted on one shaft. In adjusting this meter for full load, one element is adjusted so that it runs correct by moving either the lower or upper set of magnets in or out. Then the other element is adjusted by varying the airgap between the shunt and series coil in the other element. Light load and power factor is adjusted as before.

Instrument Transformers

One of the beauties of alternating current metering is that voltage and current capacities may be greatly increased by the use of instrument transformers. Consequently it will be found that the great majority of a.c. instruments are wound for 5 amp. in the current ranges and 100 v. in the potential ranges. Suitable transformers are then used to enable the instruments to indicate the desired current and voltages. There are two kinds of instrument transformers: the current transformers are wound with a primary designed to carry the full load current and a secondary which gives 5 amp. in the meter circuit when this load is flowing through the primary. The potential transformers have a primary designed to withstand the full primary voltage and to deliver 100 v. to the voltmeter when connected to this circuit. Wattmeters require both current and potential transformers.

Instruments Required

Let us assume that we are to install a generator to deliver 2000 kv.a. two-phase, at 4000 v. For two-phase we would need only one voltmeter and one potential transformer. The transformer should have a ratio of 4000 to 100 v., but the meter should have a full scale value of 150 v. so that 100 v. would be on the accurately readable portion of the scale. This voltmeter should then be marked to read the primary voltage, i.e., 100 v. on meter equals 4000 on scale. We may use either the moving iron, dynamometer or induction type according to our purse and requirements for accuracy.

A 2000 kv.a. two-phase generator will carry 1000 kv.a. per phase which at 4000 v. would require 250 amp. Consequently, we would need two current transformers having a ratio of 250 to 5 amp. and two ammeters having a full scale deflection at 5 amp. As before, these ammeters may be calibrated to read the primary current or in other words "5 amp. in the meter circuit equals 250 amp. on dial."

We should also have a polyphase indicating wattmeter which will require an extra potential transformer of the same ratio as before, i.e., 4000 to 100 and also a polyphase watthour meter. The two potential transformers and two current transformers may be used to supply all five instruments with sufficient accuracy. Figure 15 shows the diagram of connections.

For Clearing Installed Conduit

By E. G. Cheuvreux, Jr.

For many years, no effective method has been employed to blow down obstructions thoroughly in pipes, particularly electrical conduits, that are placed in the walls or other positions during the construction of a building. Many of these are laid in position before the cementing or plastering is completed and during the time that such work is being accomplished. It has not been found practical, by experience, to cap the ends of these pipes, although sometimes wooden plugs or waste rags are placed in the exposed ends, and oftentimes these plugs or rags, or cement are forced into the tubes to such an extent that when the pipe is sealed into position by the completion of the walls, the pipe is practically useless, unless a great deal of labor is employed to extract these obstructions.

There is no tool made at present that can be placed in the tool kit that will work successfully against all clogging in pipes. In many cases, conduits had to be abandoned and other pipes set.

A device has been patented, however, and will probably be placed on the market in the near future, that will blow down any foreign matter in conduit, such as wooden plugs, waste, cement, plaster, even ice, and on a test it blew through 200 ft. of conduit, around elbows, carrying before it all material in the tube.

The principle of the device is compression, and the tool itself is simple in construction, easily handled and safe.

Conduit is usually provided with screw threads on the exposed ends to which fittings are screwed. It is on these exposed threaded ends that the device is attached.

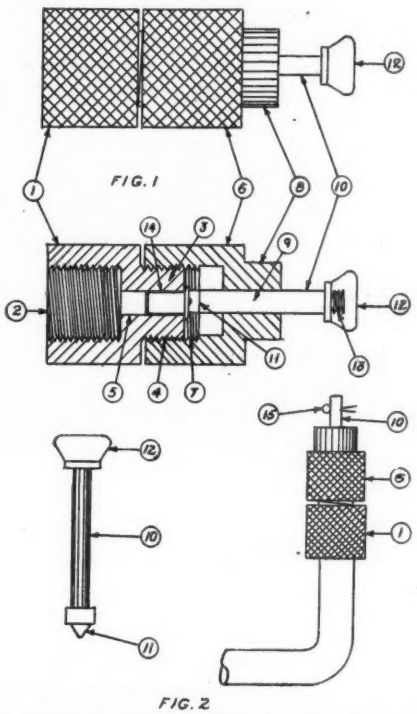


FIG. 1. PIPE CLEARING DEVICE AS ATTACHED TO PIPE
FIG. 2. SECTIONAL VIEW AND DETAILS OF PIPE CLEARING DEVICE

Figure 1 shows a fitting which may be a casting finished in black enamel or galvanized, or it may have its exterior knurled. Figure 2 shows a sectional view details of the device. The interior of one end has screw threads (2) while the other end is reduced and provided with screw threads (3) and (4), and communicating with (2) is a small bore (5). Member (6) is similar to member (1) and is also provided with screw threads (7) into which member (1) is screwed. Member (6) is also provided with a reduced portion (8), having a longitudinal passage through which the firing pin (10) passes. The firing pin consists of a knob (12) and a firing point (11). The knob or firing plate is screwed (13) to the pin itself. The pin operates freely in the passage (9) so that there is no effective pressure until the time desired.

The device is operated as follows: Member (1) is screwed to the pipe, and this member can be made in any size to suit the diameter of the pipe, and can be used on two sizes of pipe by means of reducers, and also on elbows or any fitting attached to the pipe. A blank cartridge (14) of 32 calibre is then placed in the passage (5) with its flanged end resting on the face of the passage. Member (6) is then firmly screwed to this. The firing pin will then rest loosely upon the cartridge, and a blow of a hammer on the knob will explode the cartridge. It is not necessary to have a knob, as a cotter pin may be used, as shown in (15). The explosion in the pipe will cause sufficient pressure to blow out all foreign matter. If a single cartridge does not accomplish the work effectually, a second or even a third cartridge may be used, but as a rule it will be found that one will do the work.

This device is simple and assures absolutely clean pipes on the job, and in one instance it was used for a long length of pipe (about 200-ft. run) and threw everything before it with great force.

Locating Cable Trouble

SENSITIVE VOLTMETER COMES IN HANDY. BY J. B. DILLON

IN THIS late day it seems extraneous to mention tests, such as these that follow, yet the old saying is, "Circumstances alter cases," and the circumstances may be such as to prove, after all, the advice may come in timely.

Nearly everybody concerned—as far as the need goes—is familiar with the Varley loop test, and, by the way, it is a wonder when properly used. However, we will not discuss that now, nor any of the other methods that are well known, or should be.

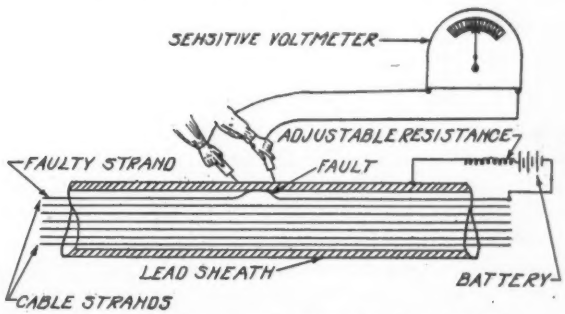


DIAGRAM TO SHOW HOW TROUBLE WAS LOCATED

I read an article some time since where somebody had secured good results locating a cross between the lead cover of a cable and one of its conductors, by merely using a battery, sensitive voltmeter, and some adjustable resistance. The theory looks plausible, therefore I have diagrammed the case and venture a little reasoning pertaining to the test.

It will be observed that one of the conductors is lying against the lead sheath, which means a ground in practice. An adjustable resistance is connected to the lead armor, the other end of the resistance connected to one side of a battery and the opposite terminal of the battery is connected to the wire involved. The voltage of the battery must be sufficient to permit 2 or 3 amp. to flow into the circuit formed.

Now, to a sensitive voltmeter flexible insulated wires are connected, the other ends of the wires entering

wooden knobs and then connecting to a sharp pointed contactor. Taking hold of the wooden knobs the prongs are held against the lead sheath, sufficiently strong to make a good contact, but not to puncture, also care must be taken to keep the prongs about 2 ft. distant from each other, while they are moved up and down or back and forth on the lead sheath.

There will be a deflection of your voltmeter until you pass the point of trouble. When you fail to get a deflection, arrange the prongs closer to one another and try to locate the "spot" where the trouble is, thereby lessening the length of armor that must be removed to clear the fault.

The reason that I think fair results can be obtained with this method is that owing to the high resistance of lead, the drop between the spreaded prongs will be sufficient to actuate a sensitive voltmeter.

That "necessity is the mother of invention" came home to me one day while I was trying to locate some crosses in a soft aerial cable 6784 ft. long, hanging on a bridge spanning the Mississippi River. The cable men were experts in reading, splicing, etc., but depended upon my galvanometer test for the location of the trouble.

I ordered several loops, but each showed too high, the normal resistance being easily calculated.

Strange, I thought, knowing the ability of the men to read the cable. There was only one conclusion and that was that the strands were burned in two and crossed up.

The trouble had to be located and it was up to me. I figured a while and then I measured two loops from one side of the river, the same two from the opposite side and then I did a little sum in averages and proportion.

It must be understood that these loop tests now being reasoned with were made without any connections at the opposite ends, but merely tested to the source of trouble, the opposite ends of the cable being left "wide open."

Let X equal the resistance of the loops from one side, Y the resistance from the other side. Each loop was reasoned with separately.

Then X plus Y is to 6784 as X is to the distance from that side. Then X plus Y is to 6784 as is Y to the distance from that side.

While the distances as computed did not tally exactly with the exact length of the cable, my averaging the tests brought it within a few feet.

"Boys, it's the best I can do. (No, we did not have any exploring coil.) I figure the trouble 212 ft. from where we are standing. The smallest fellow in the gang was called by the foreman:

"Hey, Shorty, step off 212 ft!"

"Step off nothing. Measure it!" I yelled.

The foreman shoved a cigar in my month and said:

"Chew on that. He's better than a surveyor's chain."

Reaching 212 ft. (?) he swung over on the cable like a monkey and about 10 ft. from where he swung on he hollered:

"Here it is, Captain. Rotten as hell."

The foreman shook hands with me and said I was the Candy Kid, but I often thought "more luck than sense," yet when you think it over, it was a pretty good stunt.

Synchronizing with Lamps

EXPLANATION OF THE UNDERLYING THEORY OF THE OPERATION; CONNECTIONS REQUIRED. BY J. C. GROUP

WHEN two or more sources of alternating current, such as generators, station bus-bars, lines, or any combination of these, are to be connected in parallel, it is necessary not only that the voltages be the same, but also that the maximum instantaneous voltages in corresponding phases of each source be in the same direction and occur at the same time. With these conditions present, the sources are said to be in phase or in synchronism and they may be connected together.

The conditions for synchronizing two single-phase generators are indicated in Fig. 1. Let it be assumed that generator A is running and switch R is closed so that power is being delivered to the line indicated by the leads 1-2, and it is desired to connect generator B in parallel with generator A. As the voltage of generator B is equal to that of A, the correct time to close switch S is when the maximum instantaneous voltage of the incoming generator B, which is indicated by the arrow b, is in the same direction and occurs at the same time as the maximum instantaneous voltage of generator A, which is indicated by the arrow a. The two generators, when thus connected, supply power to the line 1-2 in the direction indicated by the arrows d and e, without any tendency to circulate current around the closed circuit through the armatures of the two machines, unless the characteristics of the generators are unlike due to differences in design or to non-uniform rotation of the prime movers. The vector relations of the generator voltages in the closed circuit through the two armatures are shown in Fig. 2, where E_A represents the voltage of generator A and E_B the voltage of generator B. These voltages are 180 deg. out of phase, and being of equal value, the vector sum is zero. There is therefore no voltage present to cause current to circulate between the machines. Any displacement of the voltage of one generator with respect to the other produces a voltage in the closed circuit through the two armatures, as is indicated by Ec in the vector diagram in Fig. 3, where the voltage of generator B is shown lagging by an angle behind the current position for synchronizing represented by the dotted vector. The voltage E_C, which is equal to the vector E_A and E_B, causes a current to circulate through the two armatures and this current tends to accelerate generator B and retard generator A and thus bring them back into synchronism.

The voltage conditions in Fig. 1 are incorrect for closing switch S, if the maximum instantaneous voltage of generator B is in the direction of arrow c at the same time that the maximum instantaneous voltage of generator A is as indicated by the arrow a. The two voltages are then in the same direction in the closed circuit through the two armatures, as is shown by the vector

diagram in Fig. 4, and the vector sum of the voltages represented by Ec is equal to twice the voltage of one generator or the normal operating voltage of the system. Should the switch be closed under such conditions, the current that would flow would be limited only by the impedance of the two armature circuits and might destroy the machines. Therefore it is necessary that some means for synchronizing be provided whenever two or more sources of alternating current are to be connected in parallel.

When any number of polyphase circuits have the same direction of phase rotation, it is only necessary to synchronize with one phase, using the corresponding phase in all sources, and therefore in the discussions which follow only single-phase generators will be considered. This will be representative of one phase of polyphase generators or for any sources of alternating current other than generators.

The simplest method of synchronizing is with lamps. The principles of this method can be explained in connection with Fig. 5, where generator B is to be synchronized with generator A and the two machines operated in parallel to supply power to the line 1-2. Let it be assumed that generator A is running and the switch is open. The two lamps are connected across the poles of the switch as shown, when generator B is started. As the speed of the machine increases, the voltage will build up as soon as the field is excited and this voltage will be alternately in phase with and 180 deg. out of phase with

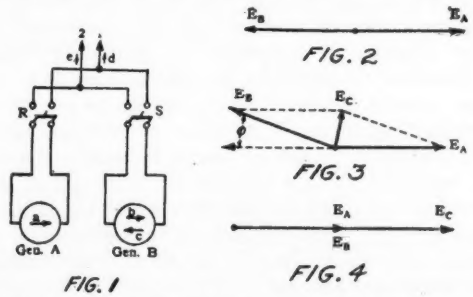


FIG. 1. CONNECTIONS FOR PARALLEL OPERATION
FIG. 2. VOLTAGES WITH GENERATORS IN SYNCHRONISM
FIG. 3. GENERATOR B SLIGHTLY OUT OF SYNCHRONISM
FIG. 4. GENERATORS 180 DEG. OUT OF SYNCHRONISM

the voltage of generator A until the speed of generator B becomes the same as that of A, when the voltages would remain in the same phase position with respect to one another. When the voltage of generator B is in phase with that of generator A, with reference to the line, no voltage is impressed on the lamps, as was explained by the vector diagram in Fig. 2 and the lamps would be dark, but when the voltage of generator B is 180 deg. out of phase with that of generator A, the voltages of the two machines operating in series, or double the voltage of one generator, is impressed on the lamps, and they burn at maximum brilliancy. Thus the flickering of the lamps gives an indication of the phase relations. When the speed of the two generators is almost the same, so that the lamps flicker slowly, the switch may be closed when the lamps are entirely dark, for then the two generators are in synchronism. The voltage of each of the two lamps must be the same as the normal voltage of the circuit, or the voltage of one generator.

Connections commonly used on switchboards for synchronizing between any generator and bus with lamps are shown in Fig. 6. The single-phase generator circuits are typical for two of any number of generators and also for one phase of polyphase circuits. The synchronizing switches provide the necessary means for connecting the synchronizing apparatus to any one of the generators and also for disconnecting the synchronizing apparatus when not needed. The switches indicated are of the rotary type and are operated by a key which can be removed from the switch when in the off position so that one key is sufficient for an entire switchboard. The development of the switch shows the connections for the two positions. In the off position all the points are open, and in the on position points 1, 2 and 3 are connected together and points 4 and 5 are connected together. The

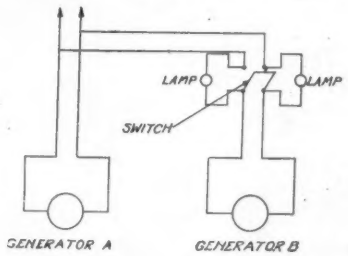


FIG. 5. SYNCHRONIZING BETWEEN TWO GENERATORS

lamp indicated by a cross is usually located on the back of the switchboard to provide the extra resistance necessary in the synchronizing circuits. The lamps shown directly above the synchronizing switches are located on the front of the panels controlling the respective generators and are the ones to be observed while synchronizing. When a certain generator is to be synchronized and connected to the bus, which is already energized by one or more of the other generators, the synchronizing key is inserted in the synchronizing switch for that particular generator and the switch is moved to the on position. Then starting with the voltage transformer connected to the generator, the side of the secondary in which the fuse is shown is connected through points 3 and 1 and the lamp on the front of the panel to the incoming synchronizing bus I, from this bus through the lamp on the rear of the board to the running synchronizing bus R, and from this bus through points 4 and 5 of the synchronizing switch to the synchronizing bus B, to which is connected the corresponding side of the secondard of the voltage transformer on the main bus. The other side of the secondaries of the two voltage transformers are connected together by the ground wire which completes the synchronizing connections. The flickering of the lamp on the front of the generator panel indicates when the generator is in synchronism with the bus. In Fig. 6 and also in almost all the figures which follow, the only connections shown are those necessary for synchronizing and the voltage transformers are indicated as being used only for that purpose, but in many cases the voltage transformers which are provided for meters may be used also for synchronizing.

Connections are shown in Fig. 7 for synchronizing between any two generators with lamps. This arrangement does not require a voltage transformer for the bus, but one for each generator is sufficient. The synchroniz-

ing switches, as indicated by the development, have three positions and two keys are used for operating them. One key when inserted in a switch will move it to the incoming position only so that points 1 and 2 are connected together, while the other key will move it to the running position only, so that points 2 and 3 are connected together. A switch must always be moved to the off position so that all the points are open before a key can be removed. One incoming key and one running key are sufficient for an entire switchboard.

Assume that generator A is running and connected to the bus and it is desired to synchronize generator B with

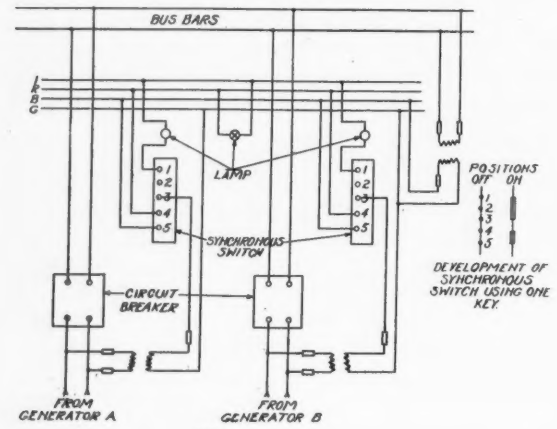


FIG. 6

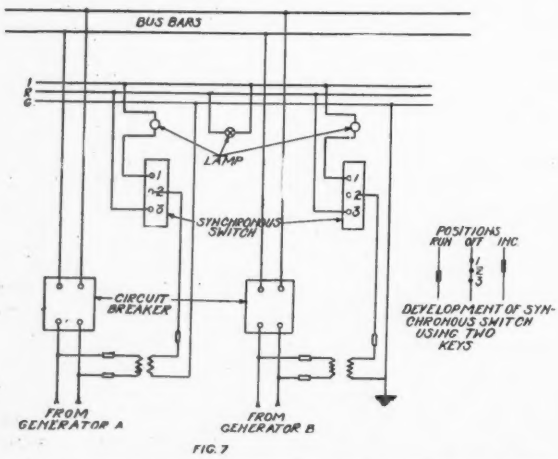


FIG. 7

FIG. 6. SYNCHRONIZING BETWEEN ANY GENERATOR AND BUS
FIG. 7. SYNCHRONIZING BETWEEN ANY TWO GENERATORS

A. First the running key is inserted in the synchronizing switch for generator A and the switch is moved to the running position and then the incoming key is inserted in the synchronizing switch for generator B, bringing this switch to the incoming position. Starting with the voltage transformer connected to generator B, the side of the secondary in which the fuse is shown is connected through points 1 and 2 of the synchronizing switch and the lamp on the panel for generator B to the incoming synchronizing bus I, thence through the lamp on the rear of the board to the running synchronizing bus R, and then through points 2 and 3 of the synchronizing switch on the panel for generator A to the corresponding side of the secondary of the voltage transformer connected to generator A. The flickering of the lamp on the panel for generator B indicates when the two machines are in synchronism. When several generators are connected to the bus and operating in parallel and it is desired to connect in another, it does not make any difference which one of the running machines is selected for synchronizing. Naturally, however, an operator would select a generator which was controlled from a switchboard panel most convenient to the panel from which the incoming machine is controlled. This method of synchronizing between machines requires one less voltage transformer than the method for synchronizing to the bus, but it requires two synchronizing keys and that two of the synchronizing switches be operated when synchronizing.

The use of lamps for indicating synchronism is quite satisfactory, but it is always difficult to judge exactly when the lamps are entirely dark. Several volts must be impressed across a lamp before the filament begins to glow, especially if the lamp has a carbon filament, and for that reason a synchronizing lamp may appear dark when actually the voltage of the incoming generator may be out of phase with the source to which it is to be connected by a considerable angle. Should the switch be closed under such conditions cross currents would circulate until the machine would come into synchronism. Furthermore, if the filament of a lamp should break while synchronizing, an operator might think that the incoming generator was in phase because the lamp was dark and close the circuit breaker at the wrong time. This danger can be averted, and the indication made slightly plainer, by reversing the secondary leads of one potential transformer, in which case the circuit breaker should be closed when the lamps are at their maximum brightness. With either connection, however, synchronizing by means of lamps is usually limited to small installations, in which the total amount of power involved is small and the inherent reactance of the generators is high. Synchronizing of larger capacity units is almost universally done by means of synchronoscopes. —The Electrical Journal.

U. S. CIVIL SERVICE COMMISSION announces examinations, applications to be rated as received until further notice, for the following positions: Electrician, $840 to $2000 a year, Application Form 1800; General Mechanic, $720 to $1000 a year, Application Forms 1800 and 2029; Steam-Electric Engineer, first and second class, $1000 to $1200 or over a year, Application Forms 1800 and 2351; Third-Class Steam Engineer, $600 to $1000 a year, Application Forms 1800 and 2351. Apply for application form and form for county officer's certificate, stating the title of the examination desired, to the Civil Service Commission, Washington, D. C. Vacancies in the Departmental Service, Washington, D. C., or elsewhere, and in the Indian Service throughout the United States, at the salaries indicated above, or higher or lower entrance salaries, will be filled from these examinations. Appointees whose services are satisfactory may be allowed the increase granted by Congress of $20 a month. Competitors will not be required to report for examination at any place, but will be rated on physical ability, training and experience.

Drives Used in Limited Space

MODERN MEANS OF SPEED REDUCTION IN CLOSE QUARTERS. BY M. A. SALLER

UNDER present day conditions where, in the average industrial or manufacturing plant, space is limited and where matters of safety and convenience receive every consideration, it is often found that in arranging for the driving of various machines and equipment the old method of belt driving is not applicable.

In order to secure good results from a standard belt drive, it is necessary that it be properly proportioned and this usually necessitates the use of long driving centers, or where the speed reduction is great, the use of a counter-shaft or jack-shaft to step down the speed, or else the use of very large diameter pulleys, all of which, of course, takes up considerable space, and often makes an awkward layout and necessitates the employment of extra expensive safety guards, etc.

Then again where the atmosphere is damp or dusty, the use of a belt drive is often unsatisfactory because of the difficulty in keeping belts tight and in good condition, and preventing excessive slippage.

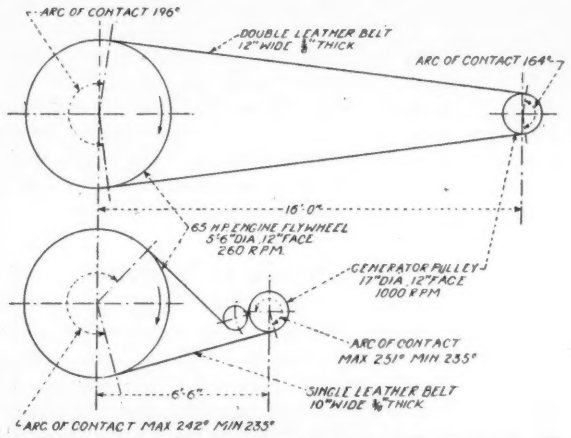
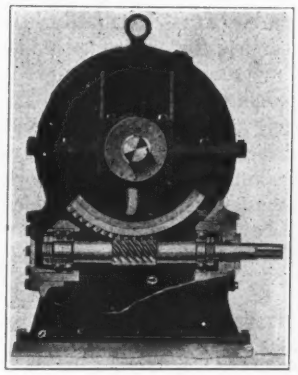


FIG. 1. COMPARISON OF STANDARD BELT DRIVE AND DRIVE WITH IDLER

Summed up, there are many occasions arising in power and industrial plant construction and operation, where other more desirable means of driving than through the standard belt connection should be considered by the engineer, and with this in mind the following alternate methods and arrangements are presented for attention:

(1) Use of idlers
(2) Spur gears
(3) Worm and gear
(4) Geared speed reducer units
(5) Chain belt
(6) Special slow speed motors

The use of a properly designed and constructed idler drive forms one of the most satisfactory solutions possible where the advantages of the flexibility of the belt drive is to be combined with compactness and close driving centers, the purpose of the idler being to increase the arc of contact to the belt on the pulley faces. These idlers can be weight or spring controlled. The attached sketch will illustrate completely the comparison between a standard belt drive and the same set of conditions taken care of by an idler drive, showing a marked saving in space while at the same time providing a more efficient traction effect on the pulley faces. Where these idler drives are used it is usually customary to use single thickness belt in order to obtain the maximum pliability, which often necessitates going to the use of a wider belt to secure a safe working tension. The possibilities for using the idler type of drive should never be overlooked,



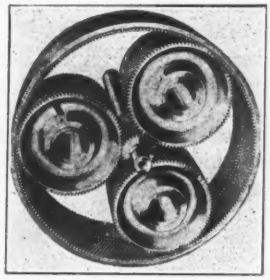


FIG. 2. WORM AND GEAR DRIVE UNIT
FIG. 3. HELICAL PLANITARY GEAR SPEED REDUCER UNIT

especially because when it is considered that a very much shorter belt length is required the cost of the drive does not materially increase over that of a standard drive.

The use of spur gears for transmitting power in close quarters is of course familiar to all, though the attendant disadvantages of inflexibility, noise, and wear are also well known. Most commercial spur gear drives comprise a large cast-iron wheel, with a smaller pinion made of steel, or such compositions as rawhide, pressed paper,

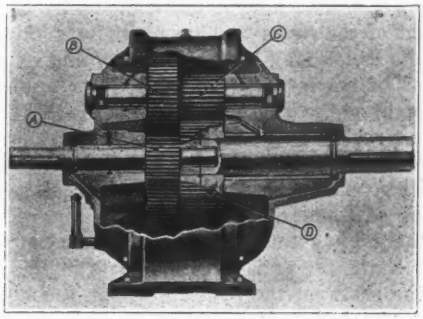


FIG. 4. SPUR GEAR SPEED REDUCER UNIT

etc., the latter being used where it is desirable to reduce the noise to the minimum. Iron and steel gears usually become noisy at a surface speed of 800 to 1000 ft. per minute, above which speed it is usually desirable to use rawhide or other pinions unless the presence of moisture militates against their use. Noise in gear drives is often caused by loose fitting bearings or the keying up of the gears isolated from a rigid bearing. On motors the

gear should be placed as close to the bearing as possible. Gears should be kept well oiled, which will reduce noise as well as wear. Rawhide gears should not be oiled but should be lubricated with talcum and graphite. Highly satisfactory gear reductions up to 10 to 1 can be made.

Where greater speed reductions are necessary, it is often desirable to shift from the spur gear drive to the worm and gear drive, which, while not so efficient as the spur gear—the latter having an efficiency of 90 to 98 per cent while the efficiency of the former will range from 70 to 80 per cent—possesses the advantage of being quiet and free from vibration. For satisfactory operation a worm and gear must be carefully machined and assembled, must be provided with bearings to take up the end thrust, and must run in oil, preferably with the worm at the bottom and running in oil constantly. In some cases, the worm and gear has the advantage that a change in direction of the drive can be made; but in other cases, this advantage becomes a disadvantage. The worm and gear drive is widely used on elevator service because the wheel will not drive the worm, as a result of which it can be used in a braking capacity. The worm and gear drive has its particular field where noiseless operation is desired, and where the speed reductions are too high to be taken care of with an ordinary spur gear arrangement.

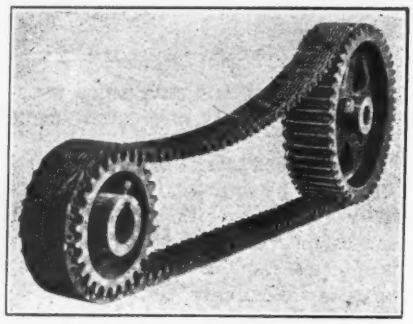


FIG. 5. TYPICAL SILENT CHAIN DRIVE

During recent years, attention has been given to the matter of speed reducing units, especially because of the advent of the steam turbine for driving pumps and other units which may be slow moving, and as a result a number of commercial "speed reducer" units have been brought on the market which seem to solve the speed reduction problem in a very satisfactory manner. Most of these reducer units take advantage of the gear principle, either making use of double helical gears, see Fig. 3, or of standard spur gears, see Fig. 4. In the latter, the high speed is received through the small diameter shaft, the end of which floats in the recessed end of the shaft on the opposite side. The high-speed shaft has attached to it a small spur gear pinion which in turn drives three other pinions, each supported on its own shaft and bearings. Each of these three pinions has attached to its shaft three other pinions which in turn drive down to the one pinion on the outboard shaft, the necessary speed reduction being obtained by the proper arrangement of ratios between these trains of gears. The entire train of gears operate in oil, while the bearings also are automatically lubricated from the oil in the casing. The use of flexible couplings is advisable on the inboard and outboard shafts. These reducer units can be made to give any desired speed reduction, simply by adding additional gear trains as the speed ratio increases. These reducer outfits have the additional advantage that they are water and dust proof.

Still another alternative is in the form of the chain belt drive which is also coming into wide use because of its adaptability under many different sets of conditions. It is claimed for this drive that it is "as flexible as a belt, as positive as a gear, and more efficient than either." It is quiet, and can be installed on close centers, and can also be used for wide reduction ratios. In arranging chain belt drives, it is best to rely on the recommendations of the engineers familiar with these drives because of the necessity for providing proper proportions between center distances, distribution of teeth on the pinions and sprockets, chain speed, etc. Generally it is advisable to run these drives in oil, enclosed in casings; they should have means for adjusting from time to time to take up stretch, and where a highly pulsating load is installed the main sprocket should be equipped with a spring hub to take up the sudden shock and jar.

The foregoing brief resumé of the various possibilities which are open to the engineer confronted with a problem of power transmission can only suggest in general the methods which could be followed, for in each case it is undoubtedly best to rely upon the judgment of the engineering concerns making the equipment for their specific recommendations covering the actual set of conditions to be met. This discussion, however, indicates the many steps which have been taken during recent years to eliminate the troubles which have followed the attempt to use the belt drive no matter what the conditions of service and installation might have been.

Preventing Spread of Vibration

THE VIBRATIONS and noise from large machines in power plant engine and generator rooms often prove annoying to people in close-by buildings. One suggestion which has been made is to cut a 2-in. air gap between the foundation of each machine and the cement, tile, or other material in the flooring of the room, the idea being that the vibrations will not jump the gap, therefore will not be transmitted to the walls of the building and thence to adjoining buildings.

Would it not be an improvement to neglect individual machines and cut such a gap in the floor, close to the wall, around the entire room? Such a gap whether around a machine or a room would be a trap for dirt if it is left open. It could be filled with an asbestos or other compressible and flexible filling which would not carry the vibrations to the wall. In time, such a filling would become covered with a hard scale; this would allow the original trouble to occur, therefore it will be necessary to watch and prevent this.

Many years ago, it was common to set machines on a hardwood frame, placed on top of the stone or brick foundation. (This was before the cement age.) I have come across several old machines set in this way. The idea seems to have been to ease the force of the vibrations for the benefit of the machine, but I believe it would also lessen the force of vibrations sent outside the building. I saw the wood frame removed from under an old engine which had been in use for 40 yr.; the wood was perfectly sound.

JAMES E. NOBLE.

Eliminating Steam Leaks

SCHEMES FOR ECONOMIZING. BY H. A. JAHNKE

IN these days of high priced fuel, an engineer should try to get as much use as possible out of a pound of coal. There are many opportunities for an engineer to economize in engine or boiler room and throughout the factory wherever steam or power is used, by studying the apparatus in his charge to see whether changes can be made to reduce the steam consumption.

There are a number of radiators located in our office which is on the second floor of the building. One day while making some repairs on the return pipe of these radiators, I noticed that these pipes were quite hot. In thinking the matter over, I decided to make use of this heat in the return pipes by running the condensate through some heating coils before it goes into the return pipe, so I installed a number of pipe coils in the room located below the office and connected the outlets from office radiators into the pipe coils, as shown in Fig. 1, where it will be noticed that the condensate from the

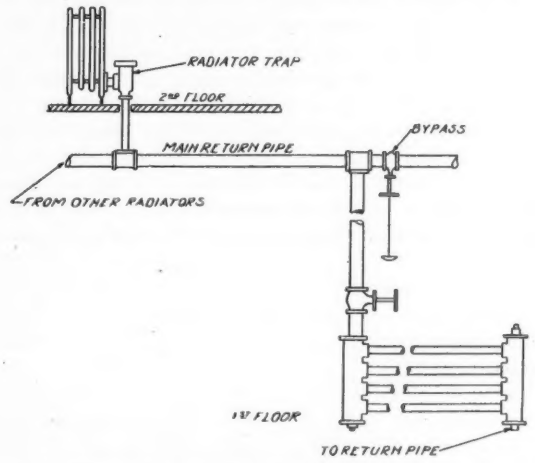


FIG. 1. RETURNS FROM OFFICE RADIATORS PASSED THROUGH PIPE COILS

office radiators discharges into one main pipe while the outlet from this pipe discharges into the inlet of the coils.

In this system we get about all the heat out of the steam, only water appears at the outlet of the coils. I also find that some of the live steam coils can be shut off during mild weather on account of these coils being heated by the condensate from the radiators, giving sufficient heat. As the steam is in the office radiators all night, it is not necessary to have all the live steam coils turned on at the first floor as was the case before, hence there is a saving in live steam day and night during the cold months.

Why could not this system be used in other plants where there are a number of floors containing heating coils? Why not run the outlet from the top floors into some of the coils in the lower floors, thereby getting more use out of the heat from the steam?

I believe this would be of great advantage especially to those plants where they do not return the water of condensation from the heating system back to the boiler, but let it go to waste. These plants also use no traps at the outlet of the coils or radiators, nor do they reduce the pressure for the heating system, but use full boiler pressure and the outlet of the coils or radiators is equipped

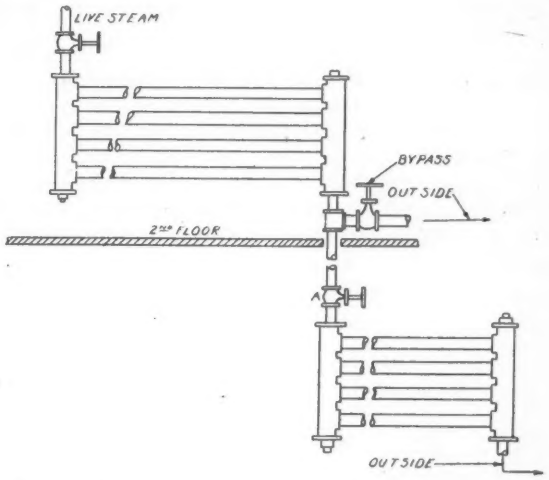


FIG. 2. RADIATOR ON FIRST FLOOR FED WITH DISCHARGE FROM RADIATOR ON SECOND FLOOR

with a globe or angle valve which is closed enough to let the condensate escape; but in an average plant where this system is in use, we see more steam than water escaping.

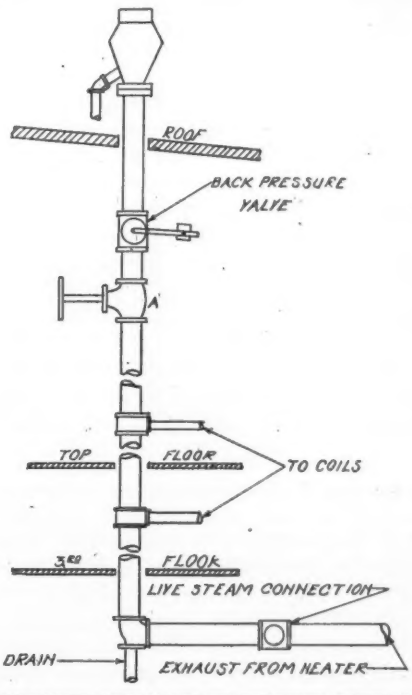


FIG. 3. EXHAUST STEAM STACK PROVIDED WITH SHUT-OFF VALVE

I believe that by connecting the outlet of the coils on the upper floors into the inlet of the lower floor coils,

much less steam would be used to keep some of the floors at the required temperature.

This could be done in the following way and is illustrated in Fig. 2, where the valve A at the outlet of the live steam coil is used as a reducing valve between the two coils; where before this condensate and steam would escape outdoors it now escapes into the coil in a lower floor, thereby giving off more heat, where it is needed more than outdoors, resulting in a great saving of the fuel bill in the boiler room.

Back Pressure Valve Leaking in Exhaust Line

In some manufacturing plants, exhaust steam from the engines, pumps and other steam using apparatus is used for heating the plant during the day, while live steam is turned into the system all night or early the next morning so as to have the temperature at the required point when work commences at the plant.

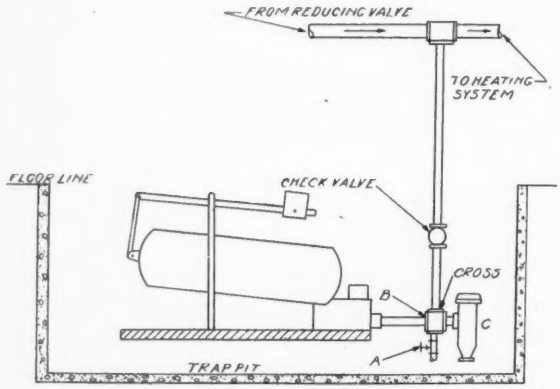


FIG. 4. PIPING ARRANGEMENT TO UTILIZE HEAT IN EXHAUST STEAM FROM TRAP

In some of these plants the piping is arranged similar to that shown in Fig. 3 and is arranged in such a way that live steam is likely to leak through the back pressure valve, should this leak or not be closed tight by using the required weights on the valve lever or rod.

Where this system is used, there should be a stop valve somewhere between the back pressure valve and heating coils on the last floor as shown at A in Fig. 3, and orders should be given to the watchman or fireman to close this valve before turning live steam into the system, after the engine is shut down or early next morning, whenever the steam is turned on. It must not be overlooked to open this valve before starting the engine.

Trapping the Exhaust Steam on a Tilting Trap

We use tilting traps of the lifting type for returning the condensate from the heating system; these lifting traps force the water into a direct return trap which returns direct to the boiler.

The exhaust from the lifting traps discharges into the heating system where the pipes are arranged as shown in Fig. 4. The pressure in the trap tank would not release as quickly as it should, so the trap tank would fill from receiver of the water of condensation. To relieve this pressure in the tank quickly, I placed the pet-cock A at the bottom of the exhaust line near the trap. This pet-cock was always partly open, so when the trap discharged the exhaust much steam was wasted, therefore I decided to place a cross where the tee B was, then connecting a small radiator trap to the cross as shown at C, little steam was afterward wasted, which occurs at the time the trap goes back into the filling position and the exhaust valve opens. The heat from the exhaust steam closes the trap quickly and all steam goes into the heating system. What steam is left in the trap tank condenses quickly. During this time, the expanding member has cooled sufficiently so that the trap is open, allowing what pressure there may remain in trap tank to escape. In this way, the pressure in the trap tank is released in time so that the water of condensation from the receiver can run into the trap tank.

With this arrangement, but little exhaust steam is wasted as was the case with the pet-cock partly open where steam was going to waste during the full time the trap was exhausting.

Whistle Valves Leaking

At some plants we notice steam continuously escaping at the whistle while nobody seems to pay any attention to the matter; in this way much steam is wasted day and night. I know it is quite impossible always to have a whistle valve tight, as they have a way of leaking more or less; but this is wasting steam unnecessarily. There should be a way of shutting off the steam on the whistle independently of the regular whistle valve, near the boiler or steam header; this can be done as illustrated in Fig. 5. In most plants the whistle is blown about three times day and it is not much trouble to open

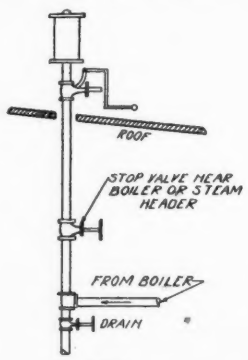


FIG. 5

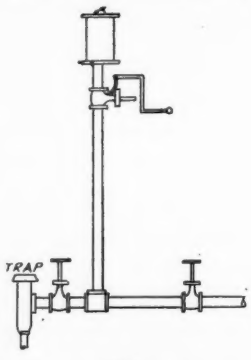


FIG. 6

FIG. 5. STOP VALVE ON PIPE TO WHISTLE
FIG. 6. RADIATOR TRAP ON WHISTLE PIPE

and close this valve at the whistle time. In this way much wasting of steam is avoided, until there is an opportunity to repair the regular whistle valve.

Frequently we notice much water escaping from the whistle when about to be blown; this is especially the case where the steam pipe from the boiler or steam header is quite long and fills with water between the whistle valve and steam main. This trouble can be avoided by placing a small trap in the steam line as shown in Fig. 6, then leading the condensate from the trap into the heater or some other place, if possible back to the boiler with other condensate.

Where much water is forced through a whistle, the full sound is not heard until all the water has escaped and during this time the whistle makes an unusual noise.

Central Oiling Systems for Power Plants

TREATMENT OF OIL FOR CONTINUOUS USE. BY R. E. LANGSTON*

EVERY known device that will assist in producing the highest mechanical efficiency in power manufacturing apparatus is used in the modern power plant. Very prominent among changes in recent years is the item of scientific lubrication.

What is meant by scientific lubrication? It means: Choosing the correct lubricant for a particular class of service; distributing the oil to the bearings through an automatic oiling system that is positive and needs no personal attention; applying the oil in such a manner that the least possible energy will be consumed in internal bearing friction; practicing the utmost elimination of waste by recovering every drop of the used oil after it has passed through the bearings, reclaiming it, and putting it back into the system.

CORRECT LUBRICATION

STREAM FEEDING of the proper quality of oil to the engine bearings is recognized as being the ultimate in perfect lubrication, and is the limit beyond which friction cannot be reduced by lubrication. Correct lubrication requires that the thinnest possible film of the most friction reducing fluid be maintained between the two rubbing surfaces. The fluid must possess sufficient cohesive property, that its film be unbroken and never permit the rubbing surfaces to come in contact, even in spots. It must not have a body any heavier than is just enough to maintain this film, for unnecessary energy will be lost in overcoming the internal friction of the fluid.

In order that the oil possessing the least amount of internal friction or viscosity can be used on a bearing and yet maintain the continuous lubrication film, it is necessary to put as much oil on the bearing as it will take and introduce it in the journal at the point of least film pressure. This flood of oil insures an unbroken film of the most friction reducing fluid; carries away worn metal, which, if allowed to remain will cause unnecessary wear; keeps the bearing cool by absorbing what frictional heat there may be generated and gives to that bearing every condition that makes perfect lubrication possible.

The merits of stream feeding of oil for bearing lubrication are unquestionable. Although when one thinks of the enormous expense necessary to keep a stream of new oil running on all bearings in a plant, the cost of this kind of lubrication seems to be almost prohibitive; but the impossible expense of flood lubrication vanishes when a system may be installed for collecting this used oil and continuously circulating it from a large reservoir to the bearings and back to the reservoir again. There is no wear-out to good oil, if it is properly separated from the impurity which it has picked up during use. Good oil may be used indefinitely with positively no chemical change and only a very small decrease in volume due to slight evaporation. When an efficient filter is added to this oil circulation system, a combination is had that will deliver perfect lubrication to all bearings at a cost that is almost nothing.

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IMPURITIES

USED LUBRICATING oil contains various kinds of impurities which it picks up during its travel through the engine bearings, drip pans, oil conductors, etc. These impurities must be entirely removed before the oil is fit for re-use. The character of this foreign matter differs with the kind of oil used, the class of service the oil is used in, bearing temperature, atmospheric conditions surrounding a plant, quality of the water and kind of boiler compounds used. The objectionable impurity is composed of grit, graphite, grease slimes, worn metal, paraffine, sludge and water, but for its clarification in a gravity filter it may be roughly classified as, first, those impurities heavier than the oil, and second, those impurities the same weight as, or lighter than oil.

Lubricating oil has been passed through sand, charcoal, sawdust, cotton waste, Fuller's earth, and even water as a means of separating from it all of those impurities which impair it as a lubricant, and make it unfit for re-use. The quality of the recovered oil generally has been pretty good after the use of these various filtering media. However, the requirements of a modern oil circulation system, in average size power plants, demand the continuous purifying of too much oil per hour for the use of a drip filter bed, of any porous material. Such a bed to be efficient and have enough capacity would have to be too large to be practical.

Oil filters of the latest design used in handling continuous flowing large capacities, resort to other methods than the use of a filter bed, composed of coarse materials. The efficiency of these new filters has been very high, for they have used the value of precipitation to its fullest extent. This precipitation action is combined with the use of a filtering medium of such material that it can present a large area of surface compactly in a small amount of space. Those impurities heavier than the oil are removed by the process of precipitation, and all impurities possessing the same weight as or lighter than oil, in which they are suspended, are removed by filtration. It is found by handling each of these two groups separately and by taking advantage of a very thorough process of precipitation, that in the filtering action, a finer medium may be used and a better quality of purified oil will be the result.

PRECIPITATION

PRECIPITATION can be the result of the action of some chemical reagent or the natural settling by gravity of any impurity heavier than oil. If the oil be permitted to stand at rest in a vessel during a long period of time, and be free from the slightest movement, all impurities held in suspension will seek a stratum in the oil depending entirely upon their relative weights. Impurities heavier than oil will rest on the bottom of the vessel, while lighter impurities will seek the surface and remain on the top of the oil. The best known example of this precipitation or separation by gravity is found in the paint bucket. The heavy coloring pigments will settle to the bottom of the bucket after separating from the

vehicle, while the lighter thinning liquids rise to the top of the bucket. The thoroughness of this separation depends upon the length of time the paint is allowed to stand at rest.

Filtration

Filtration is another name for screening the oil through a fine mesh or porous substance capable of permitting the clean oil to pass, and holding back those impurities unable to pass through the small openings. Filtration of a liquid may be compared to the screening of a dry substance. Uniform, dry, granular substances are separated from the large undesirable sizes by passing the grains through a screen. A liquid is made free of the large undesirable foreign matter by passing the liquid through a filter. The two processes are identical, for the action of the screen and the filter are the same.

Filtration is a continuous method of removing impurities, in which method time is not as much of a factor in determining its most perfect performance as is the density of the filtering material. If the liquid be allowed to pass through some material having microscopically small openings, exactly uniform in size and shape, perfect filtration of the liquid would be the result. The highest commercial degree of perfection is reached when the clarified oil has been freed from all injurious impurities and its condition returned to such a state, that, for the duty it is to perform, the oil is as good as new. To make it any better would require an expenditure out of proportion to the gain of value in the oil.

A drop of lubricating oil is composed of thousands of minute globules or molecules of oil. In a pure oil that is highly refined, there is only a very small percentage of foreign matter between these molecules, and the molecules are very close together. A poorly refined, or impure oil, contains a great deal of foreign matter between the molecules, so that a drop of this substance possesses only a few scattered molecules of real oil, and consequently is a poor lubricant.

Entrained Water

All used engine and turbine oils, due to contact with steam, collect more or less water, which must be extracted during the filtering process. Free water, or water that is in no way mixed with the oil, will settle rapidly by gravity; that is, the water is so much heavier than the oil that it falls to the bottom of the containing vessel, while the oil rises to the surface of the water. The separation is complete and almost instantaneous. Where live steam comes in contact with the oil, however, it is possible for the steam to become so entrapped in the body of the oil that it will not condense as water, but will remain suspended in the oil as vapor until a point of saturation is reached, above which the steam will collect and separate as free water. This entrained water that has been trapped between the minute globules of oil will not settle out by gravity under ordinary conditions—no matter how long the oil may remain in a state of rest. It must be remembered that every molecule of foreign matter contained in the oil, including entrained water, is so covered with a coat of oil that the oil prevents the particle from separating.

Action of Heat

When oil is heated to a temperature of approximately 180 deg. F., the cohesive force between the oil globules is temporarily weakened, sufficiently to spread the globules apart and to release the foreign impurities which are entrapped between them. This cohesive force or viscosity, possessed by the oil, is a necessary lubricating property. Nevertheless, this physical property must be temporarily changed during the process of purification. Increasing the temperature of the oil reduces this viscosity, and at a temperature near 180 deg. F. depending upon the quality of the oil, the oil loses its cohesive force and becomes "thin" as water. While at this temperature, if it be allowed to remain approximately in a state of rest for a comparatively short time, all the water and other impurities heavier than the oil will precipitate. It is upon this principle that the separator in the latest purifiers is based. So efficient is its action that only a very small per cent of the impurity is left to be removed by the filtering medium.

Filtering Materials

Of all the various kinds of filtering material used in a continuous flow oil filter for removing those impurities that will not settle by gravity, nothing has been found that can equal, in every respect, a closely woven heavy grade of cotton cloth. It is a material that is cheap and will not dissolve or possess fine particles that will work into the oil and find their way to the bearings to clog and injure them. The material provides uniform microscopically small voids or openings for the passage of oil so that the straining action will be uniformly complete. This material is such that an extended area of straining surface can be provided for the oil. It is the area of surface and not the depth of medium that does the straining. In passing a dry material through a number of screens of the same mesh, it is the first screen that does all of the separation. Any size that will pass through the first screen will pass through each of the succeeding screens having the same size openings, no matter how numerous these screens may be. This cotton cloth is of such nature that it adapts itself to the best approved mechanical arrangements, and when firm and strong will withstand many thorough cleanings before being thrown away.

The use of a low pressure head of 4 to 6 in. to force the flow of clean oil through the cloth is very desirable. For the best results, this pressure should be uniform over every square inch of the area of cloth and remain constant during its entire period of use.

When it is necessary gradually to build up a high pressure head upon the filtering medium as the sediment accumulates, a stream of dirt as well as oil will be forced through the cloth which would otherwise be completely obstructed. The only duty of a filtering medium is to separate impurities from the oil; but, if, for additional capacity, under either normal or overloaded conditions, this action has to be sacrificed to any degree, the purpose of the filter is lost.

Separation of Water

The worst impurity to separate from oil is entrained water, which is held in suspension as an emulsion. Free water separates readily, but entrained water will only settle out when the surrounding conditions are ideal. Heat at a temperature around 180 deg. F., state of absolute rest in the body of the oil, and the action of gravity during a long period of time, are all necessary conditions

which will aid in separating an emulsion, provided its resistance is not too high. While these conditions can be approximated in a continuous flow filter, it is only in a filter that will handle oil in batches, that their value may be used to their fullest extent. Better clarification of oil can always be had in a batch filter, than one built for continuous flow. The element of time which enters in their action is a most important factor.

An oil filter is a device that will remove physical impurities from dirty oil, and will retain those impurities until they are removed by some outside means, therefore, a filter that successfully performs these functions requires periodic cleaning. Whether a filter be classified as good or bad depends almost as much upon its easy accessibility for inspection and thorough cleaning as upon its capability for purification. In the selection of a type of filter for any class of service, it is important that its arrangement for accessibility be given much attention.

In view of the ever rising cost of lubricating oil and its enormous consumption in the operation of the present day industry, an efficient lubrication and filtration system, with its wonderful economical possibilities, is being welcomed as most necessary engine room equipment. Correct lubrication for the increase of plant efficiency is being acknowledged as a science.

The importance that scientific lubrication is playing in our industrial management is evidenced by the disposition on the part of large concerns toward the employment of expert lubrication service. Their duty is to search out power losses, correct wastes in the use of oils, to save time and labor by the prevention of bearing troubles, and to insure at all times more power at less cost. The central oiling and filtration system, delivering flood lubrication of a correct oil mechanically, gives just this kind of service and performs its duties automatically.

There is very little doubt that the question of lubrication in power plants is receiving more careful attention than it has in the past. There are many reasons for this, among which are the increasing demand for, and the greater cost of, oil. Lubricating oils as marketed today are the result of years of experiment, and little improvement can be hoped for in the oils themselves. The field which promises maximum results regarding efficient lubrication lies in better and more scientific methods of application, the selection of the proper grade of oil for the purpose and the reclamation of used oils so far as this is possible. While the cost of lubrication may appear small in proportion to the total production cost of power, poor lubrication and inattention to the proper use of oil will assume an importance out of all proportion to the cost of a suitable oil and attention paid to its application.

The logical solution of these conditions is the use of a central oiling and filtration system.

Saddling the War Horse

THE WAR HORSE KICKS AT CLANCY'S ATTEMPT TO EMPLOY UP-TO-DATE METHODS IN THE ENGINE ROOM. BY A. W. KRAMER

"BEGORRA! 'TIS a divil av a wurry ye are in me ould aige." Thus spoke Clancy Dorgan, chief engineer of the Star Center Lumber Co., to the 1881 model, single cylinder, 85-hp. prime mover which he had just finished repairing. "Betwane busted connectin' rods an' blowed out shtuffin' boxes ye'll be th' death av me."

Clancy and the engine had grown old together. For 35 yr. they had both decorated the engine room—the primitive engine pounding and wheezing away on one side of the room and Clancy snoring away in his chair on the other. Three times a week, regularly, the "old war horse," as he affectionately termed the engine, broke down, and at such times Clancy would have to break his sleep long enough to resurrect enough scrap material from the junk pile to "fix 'er up."

This happened to be one of those times. That morning the engine had suddenly developed a severe case of diphtheria or croup, at least so it had seemed, judging from the wheezing and groaning sounds which issued from the cylinder, and Clancy was just finishing six hours of strenuous doctoring.

Gathering up his tools and wiping some of the cylinder oil from his countenance, he shifted his chew and expectorated with marvelous accuracy into the crankpit. He was reluctant to leave and regarded the results of his labors with apprehension. One could never tell one moment what would happen the next with this prize piece of mechanism.

"Bedad, an' ye'll run now or me name isn't Clancy," he predicted. Being satisfied, however, that all repairs had been made, he made his way towards the boiler room and shouted to his able assistant who was playing a game of African billiards with two of the village idlers.

"Now, thin, Jake, lave her have a bit av stame."

Reluctantly, Jake left his game and with the aid of a hammer opened up the valve in the main steam header to the engine. "All right, Clancy," he shouted, "she's open."

This remark, however, was superfluous. It was self-evident that the valve was open—the noise which issued from the cylinder would have made that fact evident to a deaf, wooden Indian. Bang! Bang! groan, clankety clank, bang! The old engine quivered, shook, and tried its level best to knock the cylinder head into the next world.

Clancy regarded this process of starting critically. Although it was obvious that the cylinder was half full of condensate, he made no effort to open the drain cocks. Drain cocks meant nothing in Clancy's life beyond being a source of hot water for washing purposes when the engine was not running.

"Shure, an' she's got a bad case av ut, Jake, me lad," he remarked as his assistant came out of the boiler room to learn what the noise was, "—a bad case, but she'll recover, don't ye wurry. Many's th' toime oi've nursed her through a shpell as bad as this. She's a good ould war horse an' pumps wather loike she ates stame."

"But, it's makin' an awful racket," ventured Jake, not fully convinced.

"That she is, me bhoy, she shure makes a heluva commoshun but she's healthy,—she's jist loike a baby, got foine lungs an' uses thim, but ut doesn't hurt her."

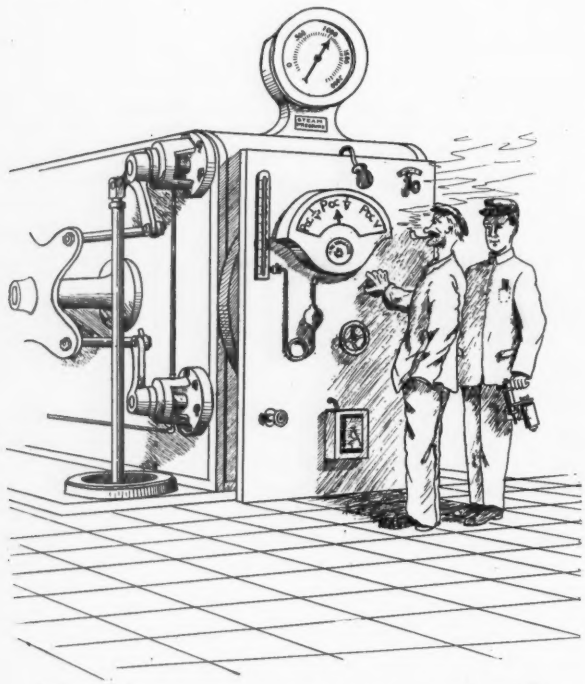
By this time most of the water had been forced out of the cylinder and the machine quieted down somewhat. Something, however, was wrong for the speed did not seem to increase as it should. The engine was running at about quarter speed although the throttle was wide open.

Clancy's eagle eye immediately detected that all was not well.

"Fwhat is ut, is ailin' th' ungrateful pace av maychanism now? Why in th' name av fortune doesn't she go?" he queried, greatly perplexed.

"Maybe its dirty inside, Clancy," suggested Jake.

"Darty me oie, wuz ut not but this afthernoon whin oi claned out th' cylinder wid a hose, wid clane wather? Shay's as clane as a whistle. 'Tisn't dirt that's the ailin' av her."



" 'TWON'T MATTER, IF OI TURN UT T' TH' LIFT?"

The engine, however, did not accelerate; in fact, it slowed down a trifle and after examining the machine a few minutes, Clancy happened to look at the steam gage. At once, the mystery cleared up. The steam pressure which should have been at 100 lb. was down to 55 lb. Naturally, the speed of the engine was reduced. Clancy wheeled around.

"Holy rocket!" he ejaculated, "all th' stame's gone. Fer the luv av Hivin, toss a shuvelful av coal in th' biler, will ye, and give us sum pressure. Fwhat is ut, a vacuum yer a tryin' t' make in th' ingin?"

"I kain't git no more pressure outen her, Clancy," remonstrated the fireman. "Luke Billings kum over this mornin' an' borrowed the rope we had tied around the safety valve t' keep it shet, an' now if I make pressure she keeps a blowin'."

"He did, did he? An' did ye stan' there loike a dummy an' lit him take ut? Yer a foine shpecimen av a foiremin t' have 'round. Begad, ye go roight over t' Luke Billings an' git that rope an' tell him if he stales our eyquipment agin, oi'll bate him up—th' darty thafe."

Jake departed and a few minutes later returned with the rope. It was only the work of a moment to tie it around the weight arm and the base of the obsolete safety valve with which the boiler was equipped. This very effectually prevented any tendency of the valve to open.

"Now, thin," commanded the chief when the foregoing operation had been completed, "let's have a bit av pressure."

The problem of raising steam being solved, Clancy watched the steam gage climb to its usual 100 lb. mark with satisfaction and he heaved a sigh of relief. The 1881 model also clanked louder and displayed greater activity. It resembled a horizontal pile driver.

"Ain't shay 'n illigent pace of maychanism, Jake, me bhoy?" inquired Clancy in admiration of his engine. "Ye know, Jake, an ingineer is got t' be raysourceful. Wasn't ut but this marnin' whin that ingin wuz actin' as if ould Nick himsilf had gotten in her? An', be jabbers, now look at her; she's runnin' loike a lady's watch. An' all bekaze oi wuz able t' fix her up wid sum stuff sumbody ilse had thrown awy—a pace av rubber hose an' a pace av angle iron."

"An' now thot she's arrunnin' agin, we're goin' t' run a tist on her," he continued.

"A test?" repeated Jake in surprise, for he had never heard of a test of any kind being performed in all the years he had been at the plant.

"Shure, a tist, ye rummy. Don't ye know fwhat a tist is? Do yet recollict thot indicathor machane oi traded fer those shpare stame gages, a couple av wakes ago?"

"That jigger with that there tin can stuck in it?" queried Jake.

"Tin can, me oie, that's th' dhrum. Th' other day oi wuz a readin' in a book an' it showed a pitcher av an indicathor machane jist loike we got an' it told how t' tist ingins wid ut. An' sez oi t' mysilf, Clancy, ye got t' run a tist an be up-t'-date. So now we're agoin' t' take sum indicathor cairds av this ould war horse t' see wuther shay's runnin' ayfficient."

"How kin ye test the engine with that there contraption?"

How? Aisy. Git th' indicathor machane out av th' box an' oi'll show yez. Oi'll git the book wid th' dhirections in ut—ut sez all about ut in the book."

While Clancy looked up the article on "Indicators and the Analysis of Indicator Cards," Jake unearthed the ancient type of indicator and blew volumes of dust out of it. A string was tangled up in the mechanism and Jake tried with all his might to pull it off, without success, however.

"There's a string catched on the blamed contraption, Clancy," he shouted. "I kain't pull it offen the can. Got a knife?"

"Shtring is ut?" inquired the chief, inspecting the cord which Jake had tried in vain to pull off. "Av coorse, uts a shtring, ye ignoorant pace av chaze. Ye jist lave that shtring roight where ut belongs. 'Tis th' coord t' pull the dhrum aroun'. Did ye clane the thing?"

"Sure, kain't ye see the dust I blew offen it?"

"All roight, thin, let's saddle th' ould war horse wud ut."

By closely following the directions outlined in the book, the indicator was finally attached to the engine and after three or four attempts a card was obtained the geometrical appearance of which pleased Clancy's fancy.

"There now, ain't that an illigant indicathor caird, Jake, me bhoy!" he exclaimed, holding the result of the operation up to view. " 'Tis a shamrock ut looks loike, begorra."

And so it did. The design far more resembled a shamrock than the usual pressure volume diagram. The result, however, pleased Clancy and while he knew nothing of indicator cards, this card puzzled him less than it would have an expert.

"Wut's the good of them lines?" inquired Jake, studying the diagram upside down. "Thought I heered ye say ye were runnin' a test."

"The Divil take yer ignoorance," exploded the chief. "Av coorse we're runnin' a tist an' 'tis this indicathor caird will tell all about ut. But now oi've got t' analoize ut t' see wut it sez."

Jake, however, had no great faith in the proceedings and made his way back to the fireroom. Clancy drew his chair up to the old table which served as a desk, lit his pipe and began to read up on indicator card analysis.

Progress in the assimilation of the required knowledge, however, was not so rapid as Clancy had expected. A host of strange terms resisted his efforts to digest the knowledge. The first proposition that puzzled him was the references to the Carnot cycle and its thermodynamic advantages. Then a maze of unintelligible symbols and frequent mention of adiabatic and isothermal expansion—terms which meant nothing to Clancy. Finally, to make matters still worse, the book brought in another cycle—a Rankin cycle this time, in which it said a perfect engine could operate. Bravely, Clancy proceeded but when the discussion turned to entropy calculations, the climax was reached and he threw the book down in despair.

"Holy St. Patrick," he ejaculated. "The spalpeen that wrote this book wuz crazy. Kairnoot cycle, Rankin-cycle! Bad cess to 'em. Oi'm goin' out an' take a walk."

Leaving the source of his mental confusion on the table, the old chief left the engine room and walked slowly down the road outside the mill. Still engrossed with thoughts of Carnot cycles and indicators, he unconsciously wandered farther than he had intended and when he suddenly became aware of this fact, he found himself before a large red building with seven enormous smokestacks.

This puzzled him, to say the least. He had never seen the place before and it appeared to be some sort of power house. Curious, he made his way cautiously to the great arched door which was open and looked inside.

His surmise had been correct. It was a power house—he could see that at a glance. But such a power house! In all his days Clancy had never seen nor heard of such a place as this; the sight held him spellbound.

Inside, on a marble floor so vast a battleship could easily have maneuvered on it, were set 24 enormous engines, all operating in perfect synchronism and without noise. They were the most beautiful machines Clancy had ever seen. The dazzling brilliancy of their polished mechanism filled the entire place with rays of reflected light which danced about in orderly confusion. The valve gear oscillating with perfect smoothness and regularity seemed like balance wheels of so many high grade watches.

Each engine was coupled to two great generators, one on each side of the flywheel. A marble panel equipped with a number of strange looking indicating and recording instruments was fitted to the cylinder head of each engine, while large steam gages adorned the tops of the cylinders. The latter evidently indicated the pressure in the cylinders.

Overlooking the engines and occupying the entire length of one side of the room was a switchboard gallery. The switchboard of polished black slate was fitted with thousands of signal lamps which, it seemed, flashed on and off incessantly. On this gallery, before a desk, sat an operator, who in response to the flashing of the signal lamps, manipulated a row of push buttons on the desk.

Attendants dressed in white moved silently about the engines, taking meter readings or sometimes making slight adjustments in the machinery.

Clancy, beholding this sight, stood dumfounded. He seemed unable to move. The immaculate walls, the vaulted ceiling ablaze with a flood of light from the impressive lighting units, reminded him of pictures he had seen of St. Peter's at Rome and of palaces. What was this place?

Curiosity finally conquered his bewilderment and he ventured inside. Slowly, cautiously, he approached the nearest engine. Even as he came close, however, he failed to hear any noise or vibration. Neither did there seem to be any heat, and when he put his hand to the cylinder, he found it cold—ice cold! Astonished, he removed his hand as though the metal had been red hot, and proceeded to examine other parts of the machine.

Finally his eye sought the steam gage on the cylinder. He read the pressure. He read it twice, to make certain. That was enough. A terrible fear suddenly gripped him. Cold sweat appeared on Clancy's brow, and although he tried to move he seemed rooted to the spot. The pressure gage registered 1000 lb. per sq. in.!

"Bedad, oi'm done fer; she'll bust in anither minute," he thought, and was in the act of rushing from the room when he almost upset an attendant who came along carrying an indicator in his hand.

"Run fer yer loife, me bhoy," cried Clancy, clutching the attendant by the arm. "Yer stame's up to a thousan' pounds. She'll shure blow up."

The operator merely smiled.

"Compose yourself," he told Clancy. "Don't be alarmed, my man. There is no danger whatever. One thousand pounds is our normal pressure.

"She won't blow up?" queried Clancy, his nerve returning.

"Indeed, no," replied the attendant. "These engines are built for that pressure."

This explained, he turned a small handwheel on the cylinder head panel which caused the engine to slow down and finally come to a stop. He next attached

the indicator to the engine. The latter proceeding interested Clancy very much.

"An' is ut a tist yer agoin' to run?" he inquired.

"No, not a test; I'm merely taking a set of cards. It's part of our daily routine. You see, these are perfect engines operating in the Rankin cycle and we have to keep close tab on them."

"Rank-in-cycle! That's ut," exclaimed Clancy. " 'Tis all aroun' oi've bin lookin' fer the Rank-in-cycle. So this is where the ungrateful thing hangs out."

"You are fortunate in finding these machines then," said the attendant. "These are the only perfect engines in existence and the only ones operating in the true Rankin cycle. All the energy taken from the steam by these machines is converted into work. No condensation takes place in the cylinders and no heat is lost by radiation because the material of which the cylinders are made—a very strong light metal—is a perfect non-conductor of heat."

" 'Tis indade 'n illigint ingin'," commented Clancy. "The Rank-in-cycle is a grand thing whin ut wurks roight. Shure oi'll be a tryin' ut on me auld war horse whin oi git back. 'Tis an illigint ingin room ye got here, sorr. Fwhat moight the name av this place be?"

"This is the 'Wireless Power Station,' the largest power plant in the world," informed the operator. "We transmit power by wireless to all parts of the world."

"Oh yis, the woireliss. 'Tis miny a toime oi've read av yez. 'Twuz an Irishman himsilf that invinted it—Mark O'Nee if oi recall th' name roightly."

The work of taking the cards having been completed, the attendant detached the indicator and started the engine by pressing a small button on the instrument panel. The great flywheel slowly increased its speed and the pointer on the tachometer crept forward. When the machine had nearly reached full speed, the attendant suddenly became very intent in observing the pointer on a strange looking gage and carefully manipulated a small handwheel at the side of the panel. For an instant the pointer oscillated violently, but it suddenly came to rest when the operator gave the wheel a last rapid twist.

Clancy, who had regarded this mysterious proceeding with interest, scrutinized the gage closely and saw that the pointer had come to rest at the designation, $P\,a\,\frac{1}{V}$

"Now fwhat the divil moight that be?" he inquired pointing to the gage and handwheel.

"Oh, that," replied the attendant, "is our P V regulator. It controls the relation between the pressure and the volume of the steam. To operate in the Rankin cycle the P V indicator must always indicate $P\,a\,\frac{1}{V}$ as you see it doing now."

"Begorra, 'tis a strange faynomenon," commented Clancy. "An' 'sposin' now that oi wuz t' turn the wheel to this here mark—fwhat 'd be the result?" Here Clancy pointed to the division marked $P\,a\,V$.

The attendant appeared amused.

"My man," he confided, "you'd probably never know the result. If you turned the regulator to that division, it would cause the steam pressure in the cylinder to vary directly with the volume. That is, if you doubled the volume, the pressure would be doubled; if you halved the volume, the pressure would be halved. Now, the clearance space in this engine is about one-tenth of one per cent. That means that the total cylinder volume is a thousand times as much at the end of the stroke as at the beginning. Suppose, now, that you turned the wheel at the instant the piston was at the beginning of the stroke and with the steam pressure as it is now, 1000 lb. As the volume increased due to the travel of the piston, the steam pressure would increase, and at the end of the stroke, if the engine could last that long, the pressure would be 1000×1000 or one million pounds per sq. in. Of course, the engine under such conditions would last only an instant of time and the explosion would probably blow you from here to Dublin."

Clancy shuddered at the thought.

" 'Tis a wicked devoice an' 'tisn't for th' loikes av me t' tich ut—" he began.

"Oh, it's safe enough when you turn the wheel to the left," interrupted the operator, "that's how we stop the engine. It's only when you turn it towards the right—towards $P\,a\,V$, and $P^2\,a\,V$ that it becomes dangerous."

" 'Tis now, oi'm commincin' to understan' yez," said Clancy. "Ye kin turn ut to the lift but not to the roight."

"That's it exactly," replied the operator. "Just try it yourself; it won't matter if the engine stops for a moment."

Vested with this degree of confidence, Clancy did not wish to appear timid. Stepping boldly up to the board he placed his hand on the wheel and inquired again to make certain.

" 'Twon't matter, if oi turn ut t' th' lift?"

"No, not to the left," answered the attendant.

"All roight thin, not t' the lift," repeated Clancy after the operator, and turned the wheel far over to the right. As he did so, however, the mistake he had made flashed upon him, but it was too late. The pointer on the P V indicator had already jumped to the $P\,a\,V$ mark. Clancy closed his eyes, and the next instant, he felt the floor under his feet mount skyward. An explosion so terrific that it seemed as if a thousand thunderbolts had been let loose shook the earth and darkness closed in about him.

"Clancy! Clancy!"

Clancy awoke with a start and found himself under the table in his own engine room desperately clutching the table legs. Jake, the fireman, in an attempt to extricate Clancy from the position into which he had fallen while asleep, was pulling both his legs.

"Clancy," he yelled, "wake up!"

"Fer th' luv av St. Patrick, let go av me laig, ye spalpeen," ordered the old chief. "Fwhat's that ye say—the fwhat blew up?"

"The cylinder head, Clancy," repeated the fireman. The cylinder head jes blew offen the ol' war horse and all the steam's blown' out of the hole."

"Ut did, did ut?" groaned the chief. "Be jabbers, 'twas the pay vay rigalator ut done ut. That's fwhat cums av a thryin' t' saddle the ould war horse."

Exhaust Steam Heating

V. K. N.'s QUESTION on exhaust steam heating on page 192, Feb. 1 issue, is the first one I have seen combining heating and condensing in one system. I do not believe in tapping the receiver of an engine or the intermediate stages of a turbine to get steam with which to supply the heating system as it has many obstacles to overcome in successful operation, principally because the load is not steady enough on the prime mover to maintain an even flow of steam at the heating end, which may also vary with its changes of shutting off or turning on some coils which rob the lower pressure cylinder or stages of the required amount of steam to keep up the power and this causes more steam to be rushed through the higher pressure side and likewise changes in receiver pressure and much unbalancing of the load between the high and low side of the prime mover. It is not necessary to put a back pressure on the engine to get steam through the heating coils or radiators. Pull it through in volume under vacuum by connecting the return pipe to the condenser chamber and using the condensate at about 100 deg. or less as condensing water, discharging at 120 deg. or more if possible. The temperature of the returns will depend much on the distance they have to travel to reach the condenser from the radiators, and the amount of heat extracted from the exhaust steam on its way through.

Why not use your radiators to do the condensing instead of jet water in the condensers? It is simply an air-cooled system in principle.

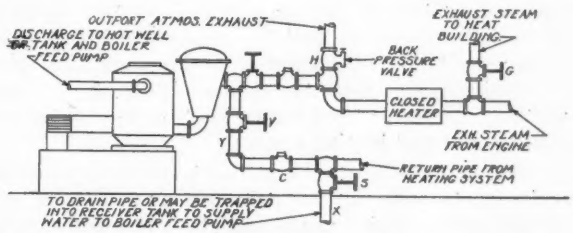
Any heating apparatus used to heat the buildings can be operated with exhaust steam without pressure if you install automatic radiator return valves on the return end of the radiator coils connecting to a return main. These valves should be set to allow live steam to be used at low pressure at night either on a vacuum return system or gravity return system if the condenser or pump should give out and no spare pump is available.

The 20 by 48 by 48-in. cylinders seem to be an odd size, as most compound engines I have seen are usually made with the low-pressure cylinder only 1½ to 2 times the diameter of the high-pressure cylinder; but if these dimensions are correct, then it is intended by the builders to use a very low receiver pressure, possibly not more than 5 to 8 lb., the governor controlling both the high and low-pressure valves.

Do not attempt to use exhaust steam for heating machines or stock in process of manufacture, if such machines or material require a sharp, quick heat as such heat cannot be obtained from exhaust steam at back pressure or vacuum, but only from live steam at medium or high pressure sufficient to carry the desired temperature from the boiler. You should measure up all pipes used for radiation and all supply lines, not covered, used for radiation, to find out how many thousand square feet of radiation are to be supplied, also to see if the condenser is large enough to handle the condensate from the return line in addition to what water is needed to condense the steam entering the condenser direct. Instead of tapping the receiver or intermediate stage, why not tap in between the heater and the engine to get the steam supply for the heating system; it is well reduced then.

An engine this size is capable of supplying more than enough exhaust steam on average load for 100,000 sq. ft. of radiators or more. The condenser must be large enough to take care of this and maintain 18 to 20 in. of vacuum on the engine piston, about 26 to 28 in. of vacuum on the condensing chamber, in order that the steam can be pulled through the system and at the same time keep the engine running condensing.

Putting a 5-lb. back pressure on the engine exhaust pipe and piston means that dispensing with the condenser would add about 28 to 35 per cent more load on the boilers, as 25 in. of vacuum on the engine is equal to saving of from 22 to 29 per cent of the total amount of steam required to carry the load. So if the exhaust steam is to be used in the heating system, it is far more economical to have the engine continue to run condensing; but it is also necessary to know whether the present radiating surface in each department is large enough to heat the rooms at the reduced pressures or vacuum heating. In some cases, it is necessary to add about 15 to 25 per cent more radiating surface to each or some of the present radiators. I have found good results from the rules used for hot water heating which varies from 1½ to 2½ times the amount of radiator surface to get the same heat at lower temperature than is obtained with high-pressure steam heat. He did not mention the pressure of the live steam heat used, whether it was boiler pressure or reduced by a reducing valve.



PUMP AND HEATER CONNECTIONS FOR A CONDENSING HEATING SYSTEM

This system is new and little has been heard of it because only large factory plants have such an immense

amount of heating to be done as to make it a problem to choose between a condensing equipment added on to the plant or to use exhaust (back pressure) steam heat, not knowing that they could use a condensing return heating system just as easily as a vacuum return heating system. The principal obstacle is the amount of water supply for condensing purposes. In this case, the condenser seems to be already in service and all that is required is to install the radiator return valves, stop all leaks in the system and make the required change in the piping. Large building plants have been running steam heat with vacuum return with from 2 in. of vacuum on the engine to 1½ or 2 lb. back pressure in severe weather. These plants would otherwise have to run on heavy back pressure, as condensing water is not available; only a small jet of city water is required at the vacuum pump to condense the vapor.

Nearly all condensing return heating systems or condensing plants use a closed heater, and in the illustration I have put the necessary additions to the sketch; G is the stop valve leading to the heating system and there should also be an oil separator on the line, a closed heater between this line and the condenser; W is a hinged check or nonreturn valve between the heater and condenser with a stem and lever attached to the valve disc. The lever can be weighted if desired, but should not be so heavily weighted as to send steam out through the back pressure valve, H, or even to destroy more than 6 to 8 in. of the vacuum on the engine piston. Set valve H at about ½ or 1 lb. pressure and valve W to hold about 18 to 20 in. of vacuum in the engine cylinder, put 25 to 28 in. of vacuum on the condenser chamber and opening valve V puts full vacuum on the return pipe to pull the returns back. C is a check valve to keep the water from returning back into the heating system when the engine is stopped. W also will keep the water from returning from the condenser to the engine and heating system.

Now, if the boilers will stand an increase in pressure of 10 lb., to make up the reduction of 6 or 8 in. of vacuum on the engine piston and also add a little more pressure on the other side of the piston, the added pressure will shorten the cutoff slightly, decrease the terminal pressure down to the same point or less and the receiver, if it dropped lower, could be raised a trifle by shortening the cutoff a little on the low pressure side. This would decrease the volume of the exhaust steam from the engine and this would require less condensing water, the while not losing much heat units of the steam from the exhaust. Choke valve W just enough to drive sufficient steam into the heating main to do the heating and let the rest go through direct to the condenser. To get best results, the heating system should be large enough to use about ⅔ of the total volume of the steam exhaust from the engine and if this is slightly reduced by change on the engine as just stated, when passing through the radiators, it is condensed and comes back in water at high temperature and only needs to be pumped out to maintain a vacuum.

If the return is too hot for the pump, put in a strainer and jet below the valve V, or partly close this valve so that no steam can escapse through into the condenser. This condensate, if 100 deg. or less, will add to the condensing water from 50 to 70 deg. of heat, and by throttling the inlet valve to regulate the amount of condensing water needed. The condensing water can be discharged from the condenser at a temperature of upwards of 120 deg. Part of this can be piped to a receiver tank to supply feed water to the feed pump and when this is discharged through the heater, the temperature will be much higher or as high as could be obtained with an open heater. This requires most careful operation and adjustment of the valves, if the point of cutoff on the engine can be materially reduced by adjustments, the less volume of steam will be required from the boilers, hence there would be a saving of all the live steam now used and no material addition of power on the engine, as 8 in. of vacuum is valued at less than 4 lb. pressure, which could be more than offset by the saving in temperature of, and the amount of condensing water required to be handled to do the same amount of work.

There is another method, that of running the engine half condensing and half back pressure, so to speak, though back pressure is not necessary; it can run with a greater vacuum on one end than on the other end. Take the exhaust steam from one exhaust valve through the heating system and back to the condenser through the condensing return line; carry about 10 in. of vacuum on this end of the engine cylinder, leaving the cutoff on this end of the cylinder a trifle long to divide the load as near evenly as possible, and turn the exhaust steam from the other end of the engine cylinder to the condenser. If the cutoff on this end were a little short so the combined mean effective pressure and 25 in. of vacuum on the piston equaled the mean effective pressure and 10 in. less vacuum on the other end, the engine would run just as steady as at present. Keep the load equally divided on both sides of the piston and between both cylinders.

Of course a system of traps could be installed on the radiator drains and connected to discharge into the return main to get the condensate water back to the boilers by a vacuum return pump, but the traps would give a lot of trouble and expense in repair, and the gain in the temperature of the returns may not be such as to make the installation of the necessary apparatus feasible. It is first necessary to find the amount of radiating surface in the buildings and the amount of space to be heated and at what temperature it is to be heated. The rest may be calculated from reference to steam tables.

There are books on heating with live, and back pressure exhaust steam, and vacuum steam heating; but to combine condensing engine equipment with a steam heating condensing return system is yet in its swaddling clothes, as few consulting engineers have advocated such, and it is now being tried in a few cases in the eastern states by some engineers who have just such problems as this case presents to solve. R. A. CULTRA.

(Note: Mr. Cultra evidently questions the advisability of extracting steam from the receiver of a compound engine or the intermediate stage of a turbine for heating purposes. Both of these arrangements, however, are common among industries of the country and are giving satisfactory service where the engines and turbines have been properly designed with this service in mind.—EDITOR.)

Gas Welding a Damaged Piston

A HAMILTON cross compound engine suddenly started to knock on the crank end of the low pressure side and was immediately shut down. The exhaust valve was taken out for inspection and a chip was found broken off the steam edge and the valve was scored as if something had passed through the valve. Next the head was taken off the cylinder and a hole was found in the follower plate, of an irregular outline about the shape of a piece of spring. The follower plate was taken off and the piece of spring was found wedged into a similar hole in the piston and protruding far enough through to hit the end of the cylinder at each stroke.

The spring had broken and then slid back and forth on the other spring and being hardened, cut a hole in both piston and follower plate, the area of which was over 3 sq. in.

The piston was taken out on the floor and a gas welding outfit and operator sent for. The holes were then filled, chipped and then filed up smooth.

During the welding process, the piston and follower plate were treated in the same manner, being heated very hot on the outside edge and gradually cooler toward the center so as to have uniform expansion. The welding time was less than 2 hr., but getting ready and waiting for the parts to cool made it a half-day job. The engine was assembled the next day and ran satisfactorily.

ABIE MALLALIEU.

Handling Heating System Returns

THE THREE SKETCHES herewith illustrate different methods of taking care of returns from heating systems and feeding into the boiler. Figure 1 shows an installation for heating with engine exhaust or by high-pressure steam. The return is by gravity through duplex traps to the boiler. The returns drain into a receiving

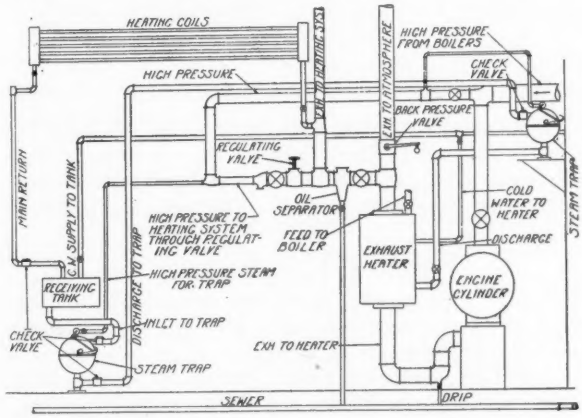


FIG. 1. HEATING BY EXHAUST STEAM OR LIVE STEAM THROUGH A REDUCING VALVE AND RETURNING CONDENSATE BY DUPLEX TRAPS

tank from which a trap on the boiler room floor gets its supply. This trap discharges to another trap at a higher elevation, which in turn discharges through an exhaust heater to the boiler. This system is applicable where the exhaust available is more than is needed for heating.

Figure 2 shows this same system using vacuum and feed pump instead of traps.

Figure 3 is an installation for heating only. A vacuum pump takes the condensate from the heating system and feeds into a receiving tank from which a

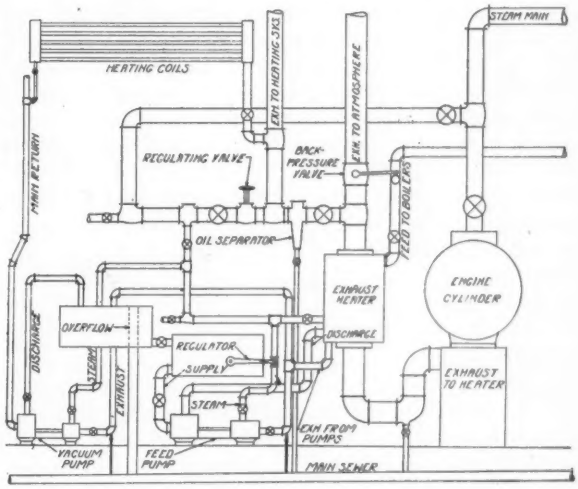


FIG. 2. HEATING WITH EXHAUST OR LIVE STEAM AND VACUUM RETURNS

feed pump takes the water and passes it through an exhaust heater to the boiler. The exhaust heater gets steam from the two pumps. H. ARMSTRONG.

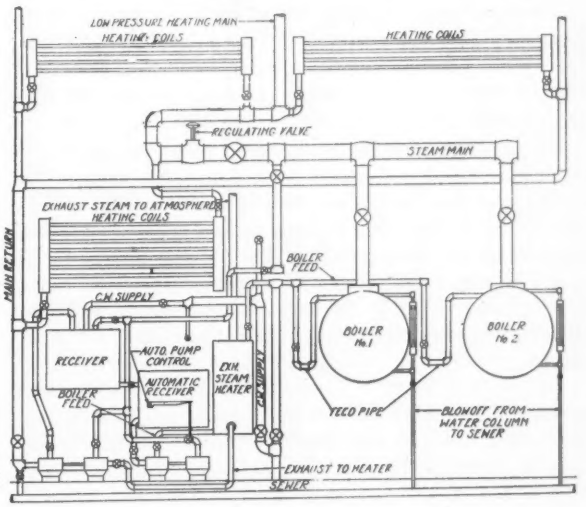


FIG. 3. LIVE-STEAM HEATING PLANT EQUIPPED WITH VACUUM PUMP. BOILERS USED FOR HEATING ONLY

Hints on Pipe Bending

SOME POINTS of great value to the man who has a job of pipe bending to do may well be added to the article on bending pipe, by W. F. Schaphorst, on page 291, Mar. 1 issue. The dry sand and resin idea has been used by plumbers for the past 40 yr. for bending lead and copper pipes.

In either of the above-named pipes, great care is necessary; the bend must not be very short, as there is danger of stretching the "heel" of the bend beyond the safe limit. I have seen such bends so thin after being short-turned that a finger pressed against the metal forced it inward.

A cold bend can be made with sand as well as with resin, but the sand must be very dry and properly packed and plugged. The proper way to dry the sand is to bake it in an oven or other very hot location for several hours, often stirring and turning the sand to allow the moisture to escape. In filling a pipe with sand, it is necessary to pack it tight by beating the sides of the pipe with a piece of hard, flat wood. Of course, one end of the pipe is plugged before starting to fill the pipe. When the pipe is filled and packed, a wood plug a fraction smaller than the internal diameter of the pipe is placed in the end on top of the sand; the plug or cap screwed onto the pipe end forces the end of the plug down on top of the sand, preventing any possibility of any small space being left at the capped end. When lead pipe is used, the ends are usually beaten in and folded over.

A good method of bending iron or other heavy pipes is to fill them with melted lead. When the lead cools, the pipe is bent to the required shape; it is then heated enough to melt the lead so that it can be run out of the pipe. Even in this case, it is necessary to plug the ends of the pipes with the plugs pressing against the lead; otherwise a perfect bend will not be secured.

JAMES E. NOBLE.

Don't Lengthen Your Wrenches

I HAVE several times seen the "kink" in print which shows how to make a wrench longer by "slipping a gas pipe over." It is a very simple procedure, and it may look and sound good to some, but I don't believe in making a wrench longer in order to put nuts on tighter.

As you doubtless have observed, wrenches for small nuts are invariably short; for medium nuts, medium in length; and for large nuts, they are long. The manufacturers therefore seem to have some "system" in making wrench lengths, and they have. The pitch of the thread is considered, the cross-sectional area of the bolt at the bottom of the threads is considered, and the strength of the man who does the tightening is also considered.

To make a wrench "twice as long" you therefore increase the tension on the bolts to twice the amount, the force of pull on the wrench being the same. By increasing wrench lengths, I have frequently actually "stretched" bolts until they broke in two, or I stopped turning as soon as I felt the bolt begin to stretch. This is poor practice, and I do not do it any more. I do not increase the wrench's length any more because I realize that the elastic limit of a bolt should never be reached.

If you feel like making a wrench longer for "unscrewing" a nut—all right. But don't make it longer for tightening. W. F. SCHAPHORST.

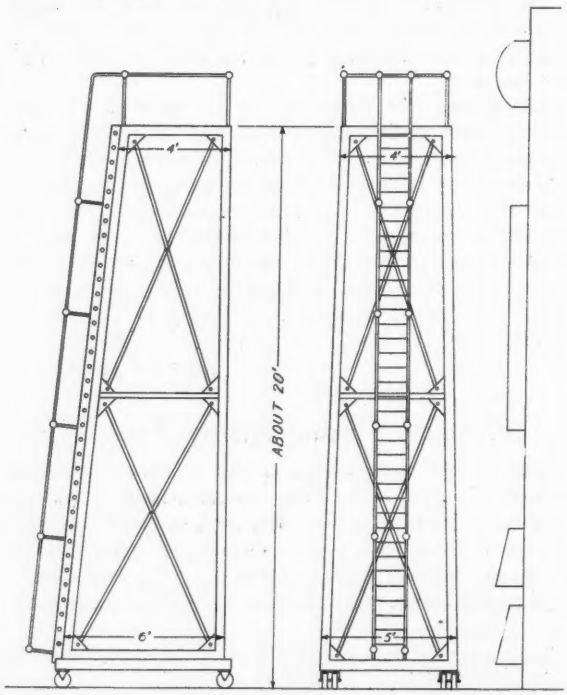
Convenient Ladder and Platform

FROM the standpoint of safety, one of the most prolific sources of accident in the boiler room is the ladder. Many times these ladders become old, crooked, dried out and dangerous, due to the liability of breaking and slipping.

In order to eliminate this danger, the foreman in a Western plant has had a movable platform, as shown on the accompanying sketch, made up of light angle iron. This platform is made light enough so that a single operator can move it around as desired. It is made wide enough so that it cannot tip over and it is made high enough so that a man can easily replace a broken gage glass when standing up on it.

The platform at the top is made about 4 ft. square and has a guard rail around it. It is reached by means of a ladder which is built into one end, this ladder being equipped with two substantial hand rails.

The wheels are equipped with a simple contrivance by which they may be locked when the platform is in the desired position.



MOVABLE LADDER AND PLATFORM FOR USE IN BOILER ROOM

This movable rig has demonstrated its value in the boiler plant many times since it was constructed and has replaced all of the various old ladders that once adorned the boiler room. CLAUDE C. BROWN.

Flywheel Kills Engineer

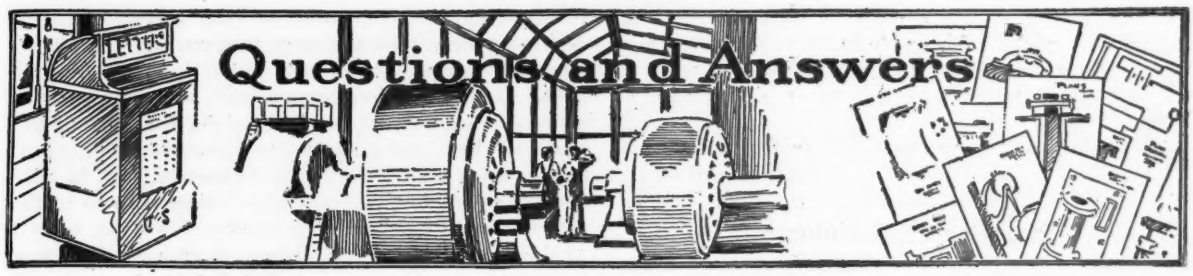
AT THE Glenrock, Wyoming, municipal lighting plant, William Blaney, engineer, 40 yr. of age, stumbled and fell into the revolving flywheel.

Irby Lam, another engineer, who was coming on duty to relieve Blaney, witnessed the mishap from a distance, and then raced to stop the engine, but too late, Blaney having been killed and the body badly mangled.

J. B. DILLON.

Preserving the Wooden Bottom of a Storage Battery Box

TO PRESERVE the wooden bottom of a storage battery box, such as is used for ignition purposes, from the quick deterioration of the acid, wash the inside of the box with water, adding a teaspoonful of baking soda to a pint of soft water. Wash occasionally. EDWARD MOEHL.



Reducing Grate Area

WE DESIRE to cut down the output of our 200-hp. B. & W. boiler to about 80 b. hp., which would mean a very slow rate of combustion for the present 58 sq. ft. of grate surface. Is there any consideration which would prohibit cutting the rear of the grate surface down by means of bricking it up so that 40 per cent of the surface will remain for the combustion of coal? You will note that this cuts the grate surface down in exact proportion to the boiler horsepower developed.

I have noticed in Power Plant Engineering that some engineers do not advocate cutting the grate surface down over one-third, but I cannot see any engineering principle which would prohibit reducing the grate to the same proportion as the capacity of the boiler is cut down. H. F. W.

Repairing Leaky Boilers

IN ANSWER to G. B., page 243, Feb. 15 issue, the most practicable, efficient and economical method of taking care of fire cracks at the girth seams of boilers over the fire is by cutting out these cracks and having them electrically welded. The only other way of permanently remedying the trouble would be to put in new lower half sheets, which is very expensive.

Patches over the fire are unsatisfactory and are not usually to be recommended.

Electric welding of fire cracks in Scotch marine boilers on steamers and locomotive boilers in railroad shops has been, for the last 10 yr., standard practice.

THE ELECTRIC WELDING CO.

Power Factor vs. Steam Consumption

I HAVE NOTED with interest the question by C. H. in the Jan. 15 number, the answer to it in the same issue, and a letter by S. D. St. Clair with editorial comment in the Feb. 15 issue. I do not believe C. H. has as yet a satisfactory answer, and submit the following:

The answer in the Jan. 15 number is entirely wrong, as Mr. St. Clair has pointed out. Mr. St. Clair, however, errs in assuming that the resistance of the distribution system enters into the problem, as it is obvious that any losses external to the generator windings would be measured by the generator watthour meter and indicated on the generator kilowatt meter. The only power factor that could be considered would be what is usually called the generator power factor and would be the cosine of the angle of lag of the currents in the generator behind the voltages in the generator. (This value would, of course, be dependent upon the conditions existing in the distribution system.)

Therefore we must conclude that the difference in steam consumption at 3200 kw., 80 per cent power factor, and the steam consumption at 3200 kw., 60 per cent power factor, would be equivalent to the added losses in the generator alone, and that they would be determined about as follows:

I have before me a test sheet for a 4000-kw., 2300-v. turbo alternator and find that the resistance between any two leads is 0.004 ohms.

The current per lead at 3200 kw. and 80 per cent power factor is 1005 amp. and at 60 per cent power factor 1340.

$$\text{Formula, } I = \frac{\text{Kw.}}{1.73 \times V \times \text{power factor}}$$

Letting I be the current per lead, R the resistance between leads and W the watts lost in winding, we have formula $W = 3/2\ I^2 R$.

Applying this, we get losses in copper at 60 per cent power factor and 80 per cent as 11,779 w. and 6060 w., a difference of 5719 w.

C. H. makes no reference to his exciter, so that the increased losses in the field need not be considered, these being supplied from an external source.

The iron losses will remain about constant, but there will be a small increase in the eddy current loss in the conductors themselves with the increased current. Also the additional heating due to the higher current in the stator and the higher temperature of the rotor will raise the stator resistance above 0.004 ohms but the increase from these minor sources will be comparatively small, are difficult to determine and had best be neglected.

The actual increase in steam consumption will be then (5719 × water rate of turbine at 3200 kw.) ÷ 1000.

In case C. H. also wants the exciter losses considered, as would be the case if the exciter were direct connected or driven direct from the generator by a motor, this could be done by actual observation, about as follows: With generator rheostat cut out read exciter volts and amperes at 60 per cent and again at 80 per cent power factor. The difference of the products would be the increased field losses (neglecting losses in field leads). This difference multiplied by the water rate divided by 1000 would give the increase in steam consumption. If greater accuracy were necessary, or if a motor-driven exciter was used, the result obtained above would have to be divided by the efficiency of the exciter or exciter set to obtain the net total increase due to excitation.

Example: At 60 per cent power factor and 3200 kw., assume a voltage of 100 and field amp. 120, making 12,000 w. At 80 per cent assume 100 v. and 100 amp., making 10,000 w. This would be a net increase of 2 kw. excitation, and if the efficiency of the exciter

were 80 per cent, would mean a total increase of $2 \div 0.80 = 2.5$ kw. This added to the 5.7 kw. increase due to generator copper loss would make a total of 8.2 kw., which would represent the total increase in losses.

I believe that this answers C. H.'s question in full.

V. E. JOHNSON.

Indicator Card Criticism

I WOULD advise H. M. R. whose indicator cards appeared in the Feb. 1 issue, to examine his piston and valves for leakage. The rapidly falling expansion line may be caused by leakage of steam past the piston, or defective seating of exhaust valves. The poor compression line is also probably due to leaky exhaust valves.

The reason for the high back pressure line is too short a cutoff on the low-pressure cylinder. Lengthen the cutoff; that will reduce the pressure, as more of the steam exhausted from the high-pressure cylinder will be used. As the card now is, the high-pressure exhaust valves open with a higher back pressure than in the cylinder at that time, forming a loop.

TOM JONES.

Length of Water Column

THE ARTICLE on page 294 of the Mar. 1 number, entitled, "What Length Water Column Would You Use?" brings up a point which I have never seen discussed before. If designing engineers would use common sense such a rule would not be necessary. To have a water column, or gage glass, extending above the top of the boiler, is not only useless but foolish, and might lead to dangerous consequences. Should a fireman attempt to fill up a boiler, such as the one illustrated in the middle diagram, to help carry him over a peak load, it does not require a prophet to tell what is going to happen.

That such misbegotten freaks do exist, though, I can certainly affirm, for I fired one once, about 12 years ago. It was on a big ditching machine and was of the vertical, unsubmerged tube type, very short and squat. The top, or steam space, was a truncated cone, 18 in. high. The steam outlet was about 9 in. from the top of this. Why it wasn't connected at the top for the steam main, I have never even been able to surmise. The top connection of the water glass was 2 in. above the top of the steam main and to comply with the provincial laws, this necessitated a glass 18 in. long, as the location of the bottom connection is always set according to the law. Now, what possible reason could there have been for putting the top connection of the glass above the height of the steam main. To my notion, it was a senseless mistake and served no useful purpose whatever.

Different boilers require different conditions and although the same dangers do not obtain for excessively high water, as they do for low water, still, they are sufficiently dangerous to demand as much care in the placing of the top connection, as they do in the bottom. I do not think there can be any rule governing the length of water columns or gage glasses, excepting one which applies to their minimum length, otherwise there would not be such a wide diversity of length possible; also, it would have to be some rule to apply to all the different types and sizes of boilers that are manufactured nowadays. If, however, your correspondent is deeply in earnest about this matter, perhaps the following suggestion may be of help to him. To be operative on all kinds of boilers, such a rule would have to be expressed as a percentage of the height, from the highest point at which heat is applied to the top of boiler, allowing a sliding scale for different diameters. Or, to offer another suggestion, why not take the square root of the distance in inches from highest point at which heat is applied to top of boiler, and have the top connection of the column or glass made at this distance from the top of the boiler.

H. A. WOODS.

THE QUESTION is asked, on page 294 of Power Plant Engineering, "What length water columns would you use?"

My answer would be, "Use the shorter glasses." It is known that the visible bottom of the water glass should be 3 in. above the top tube. On fire-tube boilers, of the diameters shown in the article it is immaterial whether the glass is 11½ in., 14 in. or 15½ in., for the plain reason that too much water will be in the boiler for safe engine operation if any one of the three is filled to the top.

As far as safety is concerned, the short 14-in. glass is often given the preference. With a long glass extending up near the top of the steam space, and a somewhat inattentive water tender on the job, there is possibility that the water will be allowed to get too high, for it is certain that many men will persist in carrying a water level up to an inch or two of the glass top. Many of us know this is poor practice, but that does not alter the fact that it is done. Therefore, all things considered, it seems reasonable to pick on the 12 or 14 in. glass.

J. E. NOBLE.

Exhaust Steam Heating

V. K. N. IN FEB. 1 issue, asks for information as to practicability of heating a plant with exhaust steam of cross-compound condensing engine. While not questioning the correctness of the answers given, I consider that he could give more details as to the heating requirements, as to whether heat was required during the entire year, whether steam was used in process requiring a definite temperature and therefore certain pressure, the percentage of load on the engine or approximate amount of steam needed for heat and amount rejected by engine running noncondensing. Although it might be possible so to arrange the piping that steam could pass through the building on its way to the condenser, but that would hardly be advisable.

I would consider running condensing in the warmer months and using the exhaust for heating in the winter provided other conditions did not prevent.

It seems to me that 85 lb. is rather low for a compound engine, so I incline to the opinion that his load is light enough to permit the foregoing suggestion being followed. It may be necessary to raise initial pressure while running noncondensing, but there are few boilers in plants having condensing engines that cannot carry more than 85 lb.

As to the pressure required for successful heating I think 2 to 3 lb. should be sufficient if the mains will carry enough steam at that pressure and a moderate

vacuum is maintained in return mains. This kind of system of course requires traps on all coils and radiators. The condensate can be discharged to hot well or open heater if the steam has been purified of oil before entering the heating system.

Several years ago we changed from live steam at 12 to 15 lb. to exhaust at 2 to 3 lb. The mains appearing rather small, I arranged a "booster" line to parallel the old one. It was also necessary to have a small amount at about 12 lb. for process, and carried 12 lb. on it, admitting some to the larger main via a reducing valve when necessary. This is usually necessary during cold weather, but it is only due to the size of the main, as there is usually some steam going through the exhaust head above the roof.

This heating main extends about 350 ft. from the boiler room and branches 150 ft. further. All told about 8 mi. of pipe are supplied in this plant and 150 traps are in use on the coils.

This change was made in somewhat of a hurry and naturally the system is not equal to one which is new and properly designed, being a collection of additions. We also had to contend with too large return mains and a few pockets, both water and air, but these were gradually eliminated and we get very good results.

I am endeavoring to get an appropriation for an additional main to parallel the present one and enable me to dispense with the "booster" connection. I intend to connect this to the last building only, where there is the greatest demand, leaving the old one to supply intervening buildings.

Although the present power requirements are higher and the heating demands fully 50 per cent greater, our coal consumption is about the same as it was 10 yr. ago.

The heating proposition in a pottery is more important than some men realize, and a growing plant presents many difficult problems.

A large factor in economical heating is well covered, properly drained pipes and good covering is one of the best paying investments that can be made.

HARRY H. YATES.

Capacity of Cylindrical Tanks

PLEASE GIVE me a rule for finding the capacity of a cylindrical tank lying horizontally, that is, a rule for finding the number of gallons at any given number of inches in depth.

Example: If a tank is 7 ft. in diameter and 26 ft. long, how many gallons will be in this tank when the liquid in it measures, say, 65 in.? J. C. R.

Some time ago, we constructed a chart for this purpose which was published in the Feb. 15, 1917, issue of the paper, at that time known as "Practical Engineer." This chart shows that, for a 7 ft. tank with liquid 65 in. high, there would be 30½ cu. ft. of liquid per foot of length of the tank, or for 26 ft. long, 793 cu. ft. This would be the equivalent of 5720 gal.

We also worked out a table dividing the tank into 20 horizontal strips of equal vertical height which can be used for getting the area of the various segments of a circle. The figures are the proportion of the total area of the circle contained in all segments from the bottom upward to and including any given strip. This table is as follows:

Segment	Per Cent Area	Segment	Per Cent Area
20	1.0000	10	0.50000
19	0.98131	9	0.43633
18	0.94796	8	0.37341
17	0.90594	7	0.31179
16	0.85762	6	0.25231
15	0.80450	5	0.19550
14	0.74469	4	0.14238
13	0.68821	3	0.09406
12	0.62659	2	0.05204
11	0.56367	1	0.01869

To get a formula that will give the area of cross section of the liquid in a tank for any depth, we will take a circle with the axis at the extremity of the vertical diameter and assume the liquid level to be at a height x above the bottom. Divide this area into a number of horizontal strips dx deep and 2y long or twice the distance from the axes to the shell. The area of each strip is 2y dx and the sum of all these areas will give approximately the total area of cross section. If we decrease the distance dx, there will be more strips and the area can be determined more accurately. If dx is made infinitely small the area found will differ from the actual area by an infinitely small amount and in the limit will be equal to the actual area. The equation for this circle is $x^2 + y^2 = 2rx$ from which $y = \sqrt{2rx - x^2}$. Substituting this value for y in the equation for the area of a strip dx deep, we get the area $A = 2\sqrt{2rx - x^2}\,dx$. Taking the summation of all such areas to a depth x and passing to the limit we get

$$A = r^2 \sin^{-1} 1 - [(x - r)\sqrt{2rx - x^2} + r^2 \sin^{-1}(x - r) \div r]$$

With a unit area, $r = 1 \div \sqrt{3.14}$ and the area

$$A = 1.5 - [(x - 0.565)\sqrt{1.130\,x - x^2} + 0.318 \sin^{-1}(x - 0.565) \div 0.565]$$

(The negative square root is used in this equation.)

Boiler Horsepower Required

WITH FEED WATER at 190 deg. F., how many standard boiler horsepower would be required for a 20 by 44 by 48-in. cross-compound condensing Corliss engine using saturated steam at 160 lb. gage, 15 lb. receiver pressure, 26 in. vacuum, 96 r.p.m., 850 i.hp. load, assuming all valve settings correct and not taking condenser pump and other auxiliaries into consideration?

H. G. E.

A. To determine the boiler horsepower required to serve a 850-hp. cross-compound, condensing Corliss engine, it would be necessary to know the water rate. This rate can be assumed for all practical purposes to be about 12 lb. per i.hp. per hr.

Therefore the engine will require 850×12, or 10,200 lb. of steam per hr., actual. The factor of evaporation, with feed water at 190 deg., steam at 160 lb., gage, is $(H - q_2) \div 970.4 = (1195.9 - 190 + 32) \div 970.4 = 1.07$.

The weight of water required, from and at 212 deg. would then be $10{,}200 \times 1.07 = 10{,}914$ lb., and the horsepower of the boiler would be $10{,}914 \div 34.5 = 317$ hp.

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Passing of the Standpipe

In the perusal of the article describing the new Broadway Pumping Station of the Toledo, Ohio, Department of Water, which appears in this issue of Power Plant Engineering, the reader will undoubtedly be more or less amused by the means employed by the engineers working on this project to convince a few skeptics of the futility of the standpipe in connection with the modern water works system. The portrayal of the incident may even cause him to wonder just why standpipes, if now not necessary adjuncts, should ever have been considered necessary. Such is, however, the case. Today, except under unusual conditions, the standpipe is no longer used, while formerly it was considered an absolutely necessary appendage to the system. A review of the development of the system of water pumpage and distribution as employed by the average city may reveal the cause of the abolition of the standpipe.

With the introduction of our existing water works systems, only estimates, or at best, perhaps, wild guesses could be made as to the ultimate consumption at the end of any given period and, as a consequence, the installation of unnecessarily large capacity pumping units was avoided by the utilization of standpipes to be used for purposes of storage during periods of light load, as an aid to the plant during peaks and frequently as a source of supply at such times as the operation of the pump might not prove convenient or economical. Another element involved was undoubtedly the unreliability of the early makes of pumping machinery and equipment. Particularly in single-unit plants, a breakdown, even if but temporary, would result in a complete tieup of the system unless, of course, a standpipe was provided to care for the demand during such an emergency.

Communities have, however, grown, and with them their water plants, and where formerly but a single unit plant sufficed the station of today may be equipped with any number of pumps, boilers, etc., and these of such design and construction as to render breakdowns exceptional. Should such, however, occur, the equipment is generally of a capacity to allow the remaining units to carry the maximum load, forcing perhaps, in some instances, being necessary. In any event, it will be found that all water pumping stations of any size and consequence are now so equipped and arranged as to insure a continuity of service without the employment of a relay in the form of a standpipe.

Breakdowns are, of course, possible, but with the reliable types and makes of boilers, stokers, piping, pumping engines, condensers and other equipment found installed in the modern station, their occurrence is rare and this too, to a great extent, accounts for the extinction of the standpipe.

Ice

As we are approaching that season of the year when this cry will again become familiar to our ears, it will be well to look into the consumer's probable demand for ice and refrigeration and into the ways and means of supplying it.

On account of the comparatively open winter which we have experienced this year, there has been an un-

usually small amount of natural ice harvested, consequently there exists a serious shortage of this commodity. What will be the result? Assuming a normal summer, it is to be expected that the demand will be normal. Who is to supply this demand and who will have to make up the deficiency of natural ice? The answer is, of course, the artificial ice manufacturers. It is the problem of these manufacturers, then, to see to it that the artificial ice supply shall be adequate.

According to a recent report, an unusually early and heavy demand for refrigerating coils is being felt and there is every indication that the coming season will see an increase, not only in the number of plants, but also in the capacities of existing plants. Is yours one of the plants being provided with additional capacity? If it is impractical or for any reason inexpedient to increase the capacity of your plant, investigate the possibilities of some other method of increasing your output. If you are in the habit of operating 24 hr. per day, it is obviously impossible to get in more hours per day, but how about getting in more days of work per season? Why not start your plant now while there is no demand and build up a reserve supply of your product to carry you over your summer peak? Is your plant in operating condition; has it been thoroughly inspected, have all the necessary inter-season repairs been made, because repairs during the rush are going to be particularly expensive this summer? Put your plant in shipshape condition and get under way.

Such a course will, of course, necessitate a large storage capacity. Have you such space at your disposal? Look into the situation. See to it that you will be able to supply your trade, this summer, with ice.

Off Duty

"Perpetual motion, me oie! How d'yez make that out?"

"Well, if ya git more out of a thing than ya put into it, isn't that perpetual motion?"

" 'Twould be that, shure, but don't yez wurry, Jim, there ain't no sich animal."

"But it says here that the device has an efficiency of 26,000 per cent. How d'ya figger that out?"

"Twinty-six thousand per cint! Shure 'tis a mut that wrote ut. Throw the book in the foire, Jim; 'tis awastin' yer toime ye are, readin' ut."

We feel, however, that Jim is not wasting his time and while we do not believe in perpetual motion or in the downfall of the law of the conservation of energy, we happen to know whereof Jim is speaking.

In a previous Off Duty talk, we discussed the peculiar boiling away of incandescent lamp filaments. In connection with lamp operation, you will remember, this boiling phenomenon was a detriment and it became necessary to suppress the action by filling the bulb with certain gases.

Suppose, however, if instead of filling the bulb with gas, we exhaust it and introduce in its interior, near the filament, a small metallic plate. If we now establish an external electrical connection between the plate and the positive terminal of the filament, a current will flow across the space between the filament and the plate when the filament glows. Should the plate be connected to the negative terminal of the filament, however, no current will flow. The current is always from the hot filament to the plate, never from the plate to the filament.

This phenomenon had been studied by scientists years before a satisfactory theory was advanced. In 1902, however, Richardson came forward with a theory which was accepted by the majority of the scientific world. According to this theory, metals and conductors of electricity contain within their bounding surfaces immense numbers of free electrons which behave like the molecules of a perfect gas. When a metal is heated, the kinetic energy of the electrons is increased and numbers of them escape across the boundary surface of the metal.

To make a long story short, however, today we know that the conductivity of the space between the plate and the filament is due to a stream of electrons which are boiled out of the hot metallic filament. We can, furthermore, control this stream of electrons by interposing a wire grid between the filament and the plate. When this grid is charged positively with respect to the filament, the number of electrons flowing through the grid to the plate is increased. When the charge on the grid is made negative, it repels the electron stream and as a consequence the current in the plate circuit is diminished. In other words, a slight charge on the plate will, in this manner, control a powerful current in the plate circuit.

This device has several important uses and is known by several different names. In connection with telephony, it is known as the telephone repeater. When this grid is connected to the receiving end of a telephone line, it will so amplify the weak talking current that it may be sent over another length of wire equal to the first. For instance in a Chicago-New York telephone line there are three such repeater stations located at approximately equal intervals. In each case, the tiny attenuated telephone current is amplified a hundred or two hundred times its value, retaining, however, all its wonderful complexity of wave form. In this manner, the repeater supplies 256 times as much energy as is put into it, and the device is said to have a telephone efficiency of 26,000 per cent.

So in this instance, we illustrate, once again, the immense practical importance of pure scientific research. Without the repeater bulb, our modern trans-continental telephone lines would probably not exist, and unless scientists had studied vacuum tube phenomena with infinite patience, and exactness, the repeater bulb of today would not exist.

Power Plant Slogans

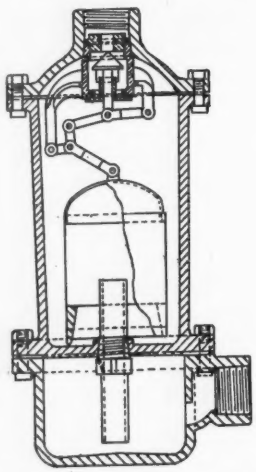
Keep and Analyze Operating Records in Every Power Plant.
Develop Water Power Sites.
Promote Health and Safety in Power Plants.
Handle Coal and Ashes Mechanically.
Employ Engineers for Engineering Work.

Trap for Pulsating Pressures

A NEW SIZE trap adapted to operate on steam mains close to engines, pumps, etc., where the pulsating pressure would cause vibration of the mechanism in an ordinary trap, has recently been placed upon the market.

This trap, shown in the accompanying illustration, has a separating chamber bolted to the bottom. A brass tube screwed into the bottom of the trap forms the only passage between this chamber and the trap proper. The tube projects nearly to the bottom of the chamber, the upper end terminating inside the bucket. A hole is drilled in the tube near the top of the separating chamber; this hole being on an angle, the end terminating inside of the tube being lower than the outer end. The inlet to the trap is on the side of the separating chamber.

In operation, water enters the separating chamber and flows to the bottom, sealing the end of the tube. Steam passes through the steam port or hole in the tube, then up into the bucket to take the place of that condensed. Thus the steam and water are separated.



TRAP WITH SEPARATING CHAMBER

Water accumulates in the chamber until its level is above the hole in the tube, sealing the hole, and then water rises up through the tube into the bucket which loses its buoyancy, sinks and the trap discharges.

All water in the chamber is then forced up through the tube and out of the trap. The momentum of the water flowing through the tube prevents steam from passing through the port until all water is blown from the separating chamber and the valve is again closed by steam floating the bucket.

Motors for Driving Boiler Feed Pumps

By J. G. WARNER

ENCLOSED or semi-enclosed type may be desirable if the pump is installed in the boiler room or in any other dirty, dusty place. The motor should preferably be of the adjustable-speed type so that the water may be pumped into the boiler at the same rate as that at which it evaporated. The rate of evaporation varies with the load.

An adjustable speed motor is one the speed of which can be varied over a considerable range or when once adjusted remains practically unaffected by the load. Examples are shunt wound, lightly-compound-wound d.c. motors. A varying-speed motor is one the speed of which varies with the load, such as a d.c. series or heavily-compound-wound motor or an a.c. wound-rotor slip-ring motor. Since adjustable-speed motors capable of sufficient speed variation for efficient boiler feed service are not ordinarily obtainable in the smaller capacities, it is necessary to use varying-speed motors for these small-capacity applications.

If a constant-speed motor is used on a boiler feed pump either the water feed must be intermittent, which is undesirable, or, if the motor continues to operate at constant speed, a part of the feed water must be bypassed through a bypass valve. Where a bypass valve is used the motor may operate continuously at constant speed and little or much of the water it pumps be admitted to the boiler by controlling the bypass valve as occasion requires. This bypass is very uneconomical because then all the water handled must be pumped against boiler pressure. Then the energy imparted to the portion of the water which is not fed into the boiler is wasted. This situation may be partially corrected in the larger plants by installing two feed pumps, each of one-half the capacity necessary for total requirements.

Gear drive is preferable to belt drive, because of high-cost maintenance. Feed pumps are frequently installed in out-of-the-way corners. Because of this the belt may slip off or break when such an accident can be least afforded.

Repairing an Air Compressor

FRACTURE CAUSED BY THE BREAKING OF A CONNECTING ROD SUCCESSFULLY WELDED BY THERMIT PROCESS

THE CONNECTING ROD of an air compressor, one of two units operated by the Erie Railroad shops, Susquehanna, Pa., for supplying air pressure to the pneumatic tools used for boiler calking, chipping boiler plate, etc., recently snapped in two, causing one end of the rod to fly around into a wedged position and exerting such a strain on the machine that the hollow cast-iron back frame of the bed plate broke off.

The cross section of the hollow casting at the fracture measured about 8 by 6 in. at this point, the thickness of two opposite walls being 3 in., the other two opposite walls only $\frac{7}{8}$ in.

A new bed plate was ordered, but it was impossible to get it delivered before 60 days. As the idleness of this air compressor cut down the compressed air supply over all the shops 50 per cent, the operators decided to repair it by means of thermit welding. In welding the casting the bed plate was laid on its side. The broken sections of the casting were then lined up by means of bolted straps, a small gap being left between the two sections to provide space for the thermit steel later to enter.

Yellow pattern wax was then inserted in the space and a mold formed around the wax. A preheating torch was directed into the mold for the purpose of dry-

ing out the mold, preheating the sections to be welded and burning out the pattern wax.

Finally, when everything was ready to make the weld, 300 lb. of cast-iron thermit, a mixture of iron oxide and aluminum, to which was added 3 per cent ferro silicon 50/50 per cent and 20 per cent mild steel punchings, were ignited in a crucible suspended over the mold. A chemical reaction at the extremely hot temperature of 5000 deg. F. was started during which the aluminum combined with the oxygen of the iron oxide to form aluminum oxide or slag, in a highly superheated molten state while the iron was set free and produced as liquid steel.

The reaction required only about 35 sec. at the end of which time the liquid steel which had precipitated to the bottom of the crucible was tapped through the bottom of the crucible into the mold, thus amalgamating with the broken surfaces of the two sections.

The metal in the weld was allowed to cool slowly after which the mold material was removed, excess metal cut off and the welded bed plate returned to service as strong as ever.

News Notes

A NEW bill will be introduced into both Houses of Congress when the special session meets providing for increased personnel and salaries for the Federal Power Commission so that it can carry out provisions of the Water Power Act. Engineers will again be called upon to support such measures. Final copies of regulations and a report of the work of the outgoing commission prepared by the Secretary are now available.

FOR YEARS, the Locomotive Superheater Co., as its name implies, has served the steam railroads of the world. In recent years, however, to render still greater service in effecting economy in fuel by the pre-heating of water, the organization has become actively engaged in the intensive development of feed water heating equipment for locomotive and marine application. With this expansion, the name of the organization has become inadequate; on March 1, 1921, therefore, the name of Locomotive Superheater Co. was changed to The Superheater Co.

H. S. GREENE has been elected Vice-President in charge of sales for the Barber-Greene Co., Aurora, Ill. Mr. Greene has been associated with the National Carbon Co. of Cleveland, Ohio, where for several years past he was assistant sales manager. He is a brother of W. B. Greene, Vice-President and Treasurer of Barber-Greene Co., and has been a director of the company for some time.

A NEW UNIT for the manufacture of belting is being rushed to completion at the plant of the Pioneer Rubber Mills in Pittsburg, Calif. The company has adopted a policy of expansion in order that its products will be delivered promptly to the industries which want them for the expected era of increased production.

THE COLLEGE OF ENGINEERING of the University of Illinois reports the following appointments which have been made since the beginning of the academic year in September: Craig Potter Hazelet as instructor in structural engineering; Arthur Michael Duff, Daniel Robert Francis and Frank Whitcher Martin, instructors in general engineering drawing; Joseph Albert Polson, associate professor of steam engineering; Clarence Walter Ham, associate professor of machine design; Arthur Hildeman Aagaard, Charles N. Arnold and Huber Ogilvie Croft, instructors in mechanical engineering; Roy Wilbur Schroeder and Glen M. Crosby, assistant superintendents of the foundry laboratory; Arthur Eilert Drucker, assistant professor of mining engineering; Harold Nevins Parkinson, instructor in railway mechanical engineering; Jean Paul Leinroth, instructor in theoretical and applied mechanics; Herbert James Gilkey, research assistant in theoretical and applied mechanics; John Will Harsch and Francis McMurtrie Howell as special research assistants in engineering materials on the investigation of the fatigue phenomena of metals.

THE BILL presented in the Colorado House of Representatives, seeking to create a law that would deny to any but citizens of the United States an engineering license, was defeated. The Colorado Engineering Council expressed their approval of the defeated bill and state their intention of seeking favorable legislative action on another similar bill, which has not as yet been placed on the calendar.

IN THE weekly report on the production of bituminous coal, anthracite and beehive coke, compiled by the Geological Survey, Department of the Interior, March 12, it is stated that the production of soft coal, which had been declining steadily since mid-December, recovered slightly during the first week of March. Whether the recovery was due to unfilled orders carried over from the week of Washington's Birthday, or whether instead it signified that the bottom of the present depression had been reached can not yet be stated. The total output, including lignite and coal coked, is estimated at 7,406,000 tons. In comparison with the holiday week preceding, this was an increase of 160,000 t., but it is more significant to note that it was 83,000 t. short of the production of the week ended Feb. 19, the latest full-time week.

The average production per working day was 1,234,000 t. Except for the period of the great strike, Nov. 1 to Dec. 16, 1919, the daily rate of production is as low at present as at any time in the past 4 yr., the period over which the records of weekly output extend.

The present coal year is far behind the year 1918-19, but that signifies little, for during that year production greatly exceeded consumption and consumers increased their stocks heavily. Neither does it mean much that the present year is far ahead of 1919-20 for in that year production was interrupted by a great strike and consumers were forced to draw on their stocks. It is more significant that the present year is over thirteen million tons behind 1917-18, a year when requirements were large and production about equalled consumption.

The production of anthracite during the first week of March, though larger than in the week of Washington's Birthday, was less than that attained in recent full-time weeks. Shipments of the nine principal anthracite-carrying roads are reported at 36,651 cars, including both steam and prepared sizes. On this basis the total production of fresh-mined, washery and dredge coal

combined, including nine fuel, local sales and railroad supply coal, as well as shipments outside the anthracite region, is estimated at 1,917,000 net tons. This was an increase of 101,000 tons over the preceding week, when production was curtailed by the observance of Washington's Birthday at many collieries. The output was still 93,000 tons, or 4.6 per cent short of that of the latest full-time week (February 14-19).

Lack of orders is the dominant factor, limiting production, in comparison with which all other factors combined were of small importance. The only district to report serious transportation disability was the Routt County, Colorado, field, where heavy snows continued to impede traffic.

U. S. Civil Service Commission announces an examination April 13 and 14, May 25 and 26, July 6 and 7, for junior engineer and deck officer to fill vacancies in the United States Coast and Geodetic Survey, at the entrance salary of $2000 a year, and vacancies in positions requiring similar qualifications, at this or higher or lower salaries, entrance salary to be increased to $2240 a year after one month of satisfactory service. A prerequisite for consideration for eligibility is that applicants shall have completed at least 3½ yr. of a course in civil engineering leading to the degree of B. S. or C. E. in a college, university, or technical school of recognized standing. Applicants must not have reached their twenty-sixth birthday on the date of examination. Age limits do not apply to persons entitled to preference because of military or naval service. Apply for Form 1312, stating the title of the examination desired, to the Civil Service Commission, Washington, D. C.

Book Reviews

"Mechanical World" Electrical Pocket Book; 377 pages, 108 illustrations; 1921 edition. Manchester, England.

Numerous additions to and changes in text appear in this edition. The section on motor-starting devices and equipment has been entirely rewritten and the treatment made considerably more extensive than heretofore. In the part devoted to a consideration of transmission, conductors and cables, which has been revised, a new table of maximum currents is introduced, while the matter on wiring systems and methods has also been rewritten and extended. Substantial additions have been made to the section on electric heating and cooking and the chapter on electric lifts is presented in an entirely new form.

Except for some few minor changes and additions consistent with the change made in the text, the illustrations remain practically as in previous editions.

Finding and Stopping Waste in Modern Boiler Rooms, Vol 2, compiled by Geo. H. Gibson of the H. S. B. W.-Cochrane Corporation; second revised edition, 414 pages, flexible cloth; Philadelphia, 1921.

A manual designed to aid the owner, manager and operator of steam boiler plants in securing and maintaining boiler plant efficiency.

The book contains over 400 pages of text, tables and charts on fuels, combustion, heat absorption, boiler efficiency, boiler testing and boiler plant management. The subject matter has been selected with a view to present only such statements as are supported by experiments and tests. A section devoted to fuels contains valuable data regarding the classification of coals and their distribution throughout the world. Improved methods of burning low-grade and waste fuels, oil, powdered coal, etc., are given considerable attention.

Sections on combustion, heat absorption, boiler efficiency and boiler testing, and boiler plant proportioning, present modern theory and practice in a clear, comprehensive manner.

The Bureau of Mines has just issued Technical Paper 269, "Analyses of Iowa Coals," by George A. Rice, A. C. Fieldner and F. D. Osgood, containing data regarding the analysis and heating qualities of numerous coals from the various producing counties of the state. The bulletin should be of interest to manufacturers, railroads, public utility plants and other large users of coal in Iowa and nearby states. It is the first in a series of similar bulletins relating to the qualities of the coals of the different seates.

According to the paper, coal was mined in a small way in Iowa in the first half of the nineteenth century. The first record is 400 t. in 1840; in 1860 the output was 42,000 t.; in 1880, 1,461,000 t.; in 1900, 5,203,000 t.; and in 1917, 8,966,000 t. These figures show that the increase has been steady, but as the coal beds are not thick and are generally irregular, the increase of production has not been as rapid as in some other states.

According to Campbell, the original coal supply in Iowa was 29,160,000,000 short tons, from which it appears that there was still available up to the close of 1910, 28,900,000,000 short tons. Since then there has been mined up to and including 1918, 60,000,000 t.

In general, the Iowa mines have a smaller output than the average of coal mines throughout the country. Because of the irregularity of the coal beds, the mines are comparatively short lived, the average mine lasting not more than 10 to 12 yr.

Iowa coals are used for locomotives, domestic purposes and power houses. The coal tends to clinker in locomotive fire boxes and under boilers where there is a hot fire, though with care in keeping an even fire it is used successfully.

For domestic purposes Iowa coal makes a smoky fire, but is satisfactory when burned in lump or nut size. The small screenings and slack are largely used in power house boiler plants.

The markets for the Iowa coal are largely local, although some coal is shipped into eastern Nebraska. A considerable amount of Illinois coal is shipped into Iowa and on the South the Illinois and Missouri coals prevent Iowa coal from moving in that direction. Colorado coal enters western Nebraska and, in fact, overlaps the Iowa markets in that state. On the east, the Iowa coal is hemmed in by the Illinois coals which are shipped up the Mississippi Valley.

The development of the coal and the output will probably continue to rise slowly with the industrial growth of the state, but no marked increase in annual production is probable. Heretofore little has been done to improve the quality of the coal except hand picking and culling at the point of loading. Much could be done to improve the coarse coal by more adequate picking tables, and to improve the small coal by building washeries at central points where mines were short lived.